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"This Emerging Technology is Revolutionary!": examining quantum science hype on online US national media

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Abstract

Purpose: While scholars are concerned about media hype of emerging science and technologies, hype remains an under-theorized construct. This study investigates the presence of multiple features of media hype using quantum science and technology as a case study.
Design/methodology/approach: We conducted a content analysis of 192 online stories about quantum science from top US national media outlets in 2022 and 2023.
Findings: Findings revealed that about 16 % of the quantum stories were exaggerated. Looking at other features, more than three-quarters of the stories failed to mention risks, and close to 70 % failed to mention the uncertain nature of quantum science. Writers with a science background were more likely to provide substantive details than those without a science background. While all exaggerated stories mentioned benefits, only less than three-quarters of non-exaggerated stories did.
Practical implications: This study has shown that online media hypes emerging science and technologies, downplaying their potential risks and uncertainties.
Social implications: This study suggests that science news consumers should still be aware of science and technology hype in online media outlets, particularly regarding risks and scientific uncertainties. News consumers can rely on science writers, compared to general beat reporters, to provide more substantive details on science stories.
Originality/value: This study makes several innovative contributions. First, this study crystallizes the media hype construct by integrating existing literature, which informed a narrow and broad conceptual definition of media hype. Second, we

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optimized the lexicon of media hype employed in extant literature when coding for the exaggeration feature in this study. Last, this is the first study to provide an in-depth analysis of how quantum science is covered in US online media outlets.

Keywords: content analysis; online news; media hype; science communication; emerging technology; quantum science

1 Introduction

"The Quantum Computing Revolution is Here" (Rocco 2024). "Cybersecurity Leader Sees Transformative Impact, Disruptive Power of Quantum Computing" (Dargan 2024). "Groundbreaking Quantum Leap: Physicists Turn Schrödinger's Cat on Its Head" (University of Warsaw 2023).

These are some of the headlines from online US mainstream and science media, including *Yahoo*, *SciTechDaily*, and *Quantum Insider*. What these headlines have in common is that they all paint a sensational picture of quantum computing, an emerging technology. Admittedly, media coverage of scientific issues is largely accurate (Wilkes and Kravitz 1992) and the public holds positive views toward media coverage of emerging technologies (Tambor et al. 2002). However, the mass media commonly hype emerging science and technologies, such as quantum science (Smith 2020), artificial intelligence (Dežman 2024; Slota et al. 2020), and stem cell research (Master et al. 2021). Although some earlier research found print media to convey the ideas that appeared in academic journal articles quite accurately to the public (Bubela and Caulfield 2004), more recent research has lamented that science is more frequently hyped in both scientific journals and public media (Caulfield and Condit 2012).

Science hype in the media is not a new phenomenon. The theoretical and practical implications of media hype have been investigated in a long-standing stream of research on this topic. Common sources of hype include journalists, scientists, politicians, lobbyists, and even social media influencers (Bubela and Caulfield 2004; Conrad 1999, 2001; Nisbet and Lewenstein 2002; Petersen 2009). Journalists hype emerging science for the social impact news value. Scientists, who often hype their own research programs for more public support, more research funding, and a quicker commercialization timeline, serve as indispensable sources for news stories (Bubela 2006; Caulfield 2018; Caulfield and Condit 2012; Soto-Sanfiel et al. 2025). In the new information environment, politicians and social media influencers also play important roles in the production, promulgation, and sustainment of hype in the media (Taschner et al. 2021). But overall, science hype is an inevitable consequence of scientists relying on funders to support their research (Rinaldi 2012). As the mass media play a powerful role in setting the agenda of public understanding of science

and technologies, framing how the public interprets scientific issues, and priming the considerations that the public takes into account when evaluating scientific issues (Scheufele 2000), science hype persists in the mass media.

Despite decades of scholarly attention, Intemann (2022) argues that hype remains an under-theorized construct. Indeed, extant research on hype is fragmented. There is a lack of conceptual consensus on what hype is, with some focusing on exaggeration or sensationalism as a defining characteristic (Bubela and Caulfield 2004; Caulfield 2018; Caulfield and Condit 2012; Dempster et al. 2022; Intemann 2022, 2023; Jarvenpaa and Makinen 2008; Roberson 2020) and others pointing to such features as an overly promotional tone (Bubela and Caulfield 2004; Liu et al. 2022) and simplification (Auch 2018). In addition to the fragmented conceptual discussions, empirical examination of these exact hype features is also lacking. Furthermore, disparate operationalizations of hype have rendered comparison of findings from different studies challenging: some research treats a high volume of media mentions as an indicator of hype (Biktimirov et al. 2021; Chen et al. 2025; Smith 2020; Vasterman 2005) while others identify characteristics of hyped media discourse (Millar et al. 2022).

Using quantum science as a case study of emerging science and technology, this paper investigates media hype in science communication. While quantum science has been considered to be the next technological revolution by the US National Science & Technology Council (National Science and Technology Council 2018), scholars have only started to explore how it is portrayed in the mass media.

To address the aforementioned critical research gaps, we conducted a content analysis of how quantum science was hyped in online US national media in 2022 and 2023. This study makes several innovative contributions. First, this paper crystallizes media hype by integrating existing literature on hype, framing theory, and norms of science communication to identify a narrow and broad conceptualization of media hype. This new conceptualization guided the operationalization of media hype in our content analysis. Second, we optimized the lexicon of media hype employed in the extant literature (Dempster et al. 2022; Millar et al. 2022) when coding for the exaggeration of science in this study. Last, ours is the first study we are aware of to provide an in-depth analysis of how quantum science is covered in US online media (for a content analysis of quantum coverage in Dutch newspapers, see Meinsma et al. 2025).

2 Literature review

2.1 Media hype of science

The mass media play a critical role in promoting science hype (Caulfield 2005). In fact, some scholars believe the media bear the brunt of the blame for hyping science

(Caulfield 2018; Caulfield and Condit 2012). Market-oriented media outlets tend to mimic each other in their coverage, prioritizing exaggeration and sensationalism over in-depth analysis due to cost considerations (Chen et al. 2025). Science news relies heavily upon the research community for sources and scientists themselves have been increasingly hyping science over the past decades (Caulfield 2018; Chiu et al. 2017). Researchers often feel pressured to exaggerate their discoveries in order to match their peers' hyped expectations (Caulfield 2018; Grebenshchikova 2024; Scheufele 2013). Many of them also endorse technology optimism that downplays uncertainties in science to gain more funding support (Hjörleifsson et al. 2008); this optimism is also transmitted through university press releases, which are routinely uncritically repurposed as news stories and media interviews (Heyl et al. 2020).

Media hype of science is thus an integral part of scientific research (Caulfield 2018). An analysis of health research abstracts published between 1974 and 2014 revealed that positive words had increased ninefold compared to a 2.6 times increase for negative words and that the use of hyped language in scientific writing had risen 880 % over the study period (Vinkers et al. 2015). One content analysis study of peer-reviewed genetic research covered in newspapers reported 11 % of stories with moderate to high hype and 26 % with some slight hype (Bubela and Caulfield 2004). Another study comparing university press releases with news stories in South Africa reported that hype was present in about one third of the science stories (Heyl et al. 2020).

Science hype in the media is a double-edged sword. On the positive side, hype sets agendas, mobilizes resources, attracts funding, and builds political and public support for science (Caulfield 2018; Grebenshchikova 2024; Roberson 2020). For instance, the National Aeronautics and Space Administration (NASA) used hype rhetoric to raise media attention, increase people's support and get funding for exploring Mars (Roberson 2020). But this hype strategy also marginalized other alternatives to explore Mars, amplifying blind spots and limiting scientific research in this field (Roberson 2020). Exaggerated discourse may also mislead audiences who lack the expertise to detect hyperbole, resulting in biases and even causing harm (Intemann 2022). Furthermore, hype may inflate expectations about scientific discoveries and lead to a backlash, such as eroding people's trust in science, when results lag (Grebenshchikova 2024).

2.2 Two types of hype

Kari et al. (2023) distinguished between two media hype types: discursive hype and semantic hype. Discursive hype is identified by the volume of media coverage on an

issue while semantic hype deals with the nature of media coverage (e.g., whether the media cover an issue in an exaggerated tone). These two types of hype do not always co-occur (Kari et al. 2023).

Vasterman (2005) provided an oft-cited definition of discursive media hype: "a media generated, wall-to-wall news wave, triggered by one specific event and enlarged by the self-reinforcing processes within the news production of the media" (p. 515). To Vasterman (2005), hype is characterized by the amplification and magnification of media coverage. One popular way to measure discursive media hype is to capture the volume or intensity of media coverage on a topic (Biktimirov et al. 2021; Chen et al. 2025; Smith 2020; Vasterman 2005), resting upon the assumption that hype signifies mounting media attention to an event (Ruef and Markard 2010). In his conceptualization, Vasterman (2005) specifically excluded exaggeration and distortion as defining features of hype because he believed they were too subjective and hard to measure.

Semantic hype, on the other hand, focuses on the tone and content of media coverage, which will be the focus of the current study. The most frequently mentioned feature of semantic hype in the extant literature is exaggeration or sensationalism (Bubela and Caulfield 2004; Caulfield 2018; Caulfield and Condit 2012; Dempster et al. 2022; Intemann 2022, 2023; Jarvenpaa and Makinen 2008; Roberson 2020). Employing "grandiose, extravagant, or extreme" (Smith 2020: 502) language, exaggerated hype over-blows some kernel of truth (Troiano et al. 2018), often inappropriately highlighting that emerging science or technology has more benefits than warranted by reality (Caulfield 2018) or simplifying the content or nature of scientific research (Chen et al. 2025).

In addition to writings on exaggeration, a rich body of literature on how emerging technologies are framed in the mass media and what norms are prevalent in science communication have pointed to at least two more features of semantic media hype: benefit-risk imbalance and oversimplification of science.

2.3 Framing and benefit-risk imbalance in semantic media hype

Framing is the process of selecting certain aspects to focus on when communicating an issue to the audience (Entman 1993). Journalists engage in an active process of framing by establishing media frames, which are "structures that draw boundaries, set up categories, define some ideas as out and others as in, and generally operate to snag related ideas in their net in an active process" (Reese 2007: 150). Framing is especially powerful when the public has little knowledge of emerging science and technologies, and therefore people rely upon multiple information sources,

particularly the mass media, to make sense of these new phenomena (Ho et al. 2013). Despite the wide variety of emerging technologies they cover, science journalists adopt some common media frames in their stories, amongst which benefit and risk frames dominate early coverage of emerging technologies (Weaver et al. 2009), such as nanotechnology (Donk et al. 2012) and artificial intelligence (Nguyen and Hekman 2024).

Even though each emerging scientific and technological innovation comes with both benefits and risks (Binder et al. 2012), media hype is prone to overstate the capabilities without due acknowledgment of potential risks (Liu et al. 2022). Playing up the benefits, particularly near-term economic and social benefits, to attract immediate funding and investment and downplaying the risks or the unknowns of research is another commonly discussed feature of media hype (Caulfield 2004, 2018; Caulfield and Condit 2012; Intemann 2022). A content analysis of genetic research found only 15 % of newspaper stories and about 5 % of science stories mentioned risks while 97 % discussed benefits (Bubela and Caulfield 2004). Another recent analysis of artificial intelligence in the Chilean news media also reported that critical perspectives were not given much mention (Barragán et al. 2025). Such benefit-risk imbalance is a reflection of techno-optimism, the belief that technology will solve all society's problems and bring a better world (Hjörleifsson et al. 2008). An extreme case of techno-optimism is techno-utopianism, where all potential risks with the development of technologies are ignored (Buchanan 2024). One of the consequences of downplaying risks is that media hype about science often results in overly promotional stories (Caulfield and Condit 2012), which can drum up interest and excitement among the lay public (Meyer et al. 2023), another reason why science communication employs hype. It should be acknowledged that media hype of science is not only the product of journalists but also of scientists, their institutions, and investors as these groups often use overly promotional language to generate interest and trust from other investors and the public (Powers 2012).

2.4 Science communication norms and oversimplification of science in semantic media hype

In addition to exaggeration and benefit-risk imbalanced reporting, hyped media stories also tend to paint a simplified picture of a sophisticated scientific topic whose long-term impact and ramifications are generally uncertain. Traditionally, simplification has been upheld as a critical news value (Östgaard 1965) since the general public pays more attention to simple news content (Shulman et al. 2024). It is also a celebrated norm in science communication as scientists simplify the complexities of research when they popularize their work (Salzmann et al. 2025; Scharrer et al. 2017).

While simplification can ease understanding of sophisticated scientific topics, it can also prevent the public from gaining a more nuanced and deeper understanding of science. As the boundaries between science and journalism are increasingly blurred and biased information about science continues to flood the media environment, scholars take notice of new science communication norms. For instance, Brüggemann et al. (2020) advocated for knowledge journalism, i.e., providing in-depth knowledge about science. They argued that science journalists should put scientific facts into context, such as what methods were used to reach scientific findings and the social context where science was done. Echoing this perspective, Gelfert and Schneider (2025) proposed justification reporting as a new news norm where science journalists should cover both the strengths and weaknesses of a scientific hypothesis to justify the conclusions in the story. Hype can occur when the research findings are poorly contextualized or not contextualized at all in news stories (Auch 2018). This is not to claim that hyped stories are necessarily wrong. While some scholars consider inaccuracy to be a characteristic of hype, others disagree. For instance, Smith (2020) argues that "hype is not an inaccurate forecast but rather an expectant kind of language, rhetoric, or discourse" (p. 502).

In addition to lack of depth, another manifestation of simplification is failure to address scientific uncertainties. Uncertainty is integral to the scientific enterprise. It can manifest itself as deficient uncertainty (i.e., we know that science cannot explain some phenomena yet), technical uncertainty (i.e., some research methods have certain limitations, such as measurement errors), scientific uncertainty (i.e., science only provides provisional truth), and consensus uncertainty (i.e., mixed scientific evidence or conflicting viewpoints among experts) (Gustafson and Rice 2019; Guo et al. 2025). Scientific uncertainties are particularly conspicuous in quantum science research where not only the scientific discovery itself may be uncertain but the social, political, and ethical implications are also uncharted domains. However, science journalism routinely eschews acknowledging uncertainties of science to make news stories more comprehensible (Retzbach and Maier 2015). Hyped media stories, in particular, tend to ignore uncertainties associated with emerging technologies (Ratcliff and Wicke 2023). For instance, media coverage of personalized medicine and genetic research ignored study limitations or caveats (Caulfield and Bubela 2004; Marcon et al. 2018). Consequently, Brüggemann et al. (2020) proposed transparency as another emerging science communication norm where reporters were expected to discuss the process of research and address uncertainties in science news.

It should be noted that semantic media hype can entail multiple features described above. For instance, Heyl et al. (2020) characterized hype as "exaggeration for the purpose of attracting attention or exacting an emotional reaction from the

reader" and "content (that) could be interpreted as over simplifying or overgeneralizing the topic being discussed" (p. 135).

Based on our review of the extant literature, semantic media hype can be characterized by *the exaggeration of facts in news stories*. More broadly speaking, semantic media hype can be defined as *the practice of the media to exaggerate facts and present an overly optimistic and simplified picture with a focus on near-future benefits for sensationalism*.

2.5 Study context: quantum science and technology

With its focus on studying particles and energy on extremely small – atomic and subatomic – scales (Roberson 2021), quantum technology is an emerging technology given its fast scientific development and uncertain practical applications (Coccia and Roshani 2024; Purohit et al. 2024). Core quantum mechanics principles, such as wave-particle duality, underpinned the first quantum revolution that brought lasers and MRI machines into use (Dowling and Milburn 2003). Now scholars anticipate a second quantum revolution where quantum principles – such as superposition, entanglement, and contextuality – will galvanize the development of new technological applications (Dowling and Milburn 2003; Meinsma et al. 2023). The high potential impact coupled with low public engagement with quantum science has recently prompted the United Nations to proclaim 2025 as the International Year of Quantum Science and Technology (American Physics Society 2024).

Like many emerging technologies, some scholars have already started to bemoan the substantial hype surrounding quantum science and technology right now. The hype starts with the research community. Roberson (2020) contended that when scientists talked about "quantum supremacy" and "quantum revolution," they were hyping the impact of quantum technology given its actual nascent stage of development. An analysis of TEDx talk videos on YouTube found that quantum technology videos mentioned benefits six times more than risks (Meinsma et al. 2023). By echoing similar language and sentiment, the mass media also hype quantum science and technology (Smith 2020). Some researchers have expressed frustration over quantum hype in the popular press, arguing that most of the hype does not stand up to scrutiny (Horgan 2016). Even worse, some claim that hype can cause inaccurate, distorted, or false beliefs about quantum science and technology (Meyer et al. 2023). Attention to hyped topics undergoes a predictable cycle and hype is most likely to emerge when there is a new discovery that generates public enthusiasm (Wien and Elmelund-Præstekær 2009). According to the Gartner Hype Cycle (Fenn and Raskino 2008), a popular framework that maps out hype evolution phases,

quantum technology reached the peak of inflated expectations in 2021 and will not plateau until at least a decade later (Harvey 2021).

Despite frequent references to quantum hype in the literature, no empirical research has been conducted to quantify the extent of quantum hype in the mass media. We will fill this gap by conducting a content analysis of how quantum science is portrayed in online US national media. We focus on online media in this study because Americans are more likely to get their news from digital devices (86 %) more than from TV (63 %), radio (42 %), or print publications (26 %) (Pew Research Center 2024). Hence, we propose the following research question: *(RQ1) What is the extent of quantum science hype in online US national media?*

2.6 Does it matter if writers have a science background?

Multiple actors engage in science communication online and play diverse roles. Analyzing writers' background on four Israeli science websites, Ginosar et al. (2024) found that only 64 % were reporters or scientists who frequently published stories within and outside their expertise domains and 10 % were scientists who published stories only in their own specialty areas. Through interviews with journalists and writers, Fahy and Nisbet (2011) concluded that some science journalists held traditional journalistic roles online while others served more diverse functions, such as curators, conveners, public intellectuals, and civic educators.

The background of the science news writer may shape the tone and content of the published story. Most journalists are generalists while some focus on specific topic areas, known as beats. It is not surprising that a science and technology beat journalist should have more exposure to and domain expertise in emerging science and technology topics, such as quantum science, than a general beat reporter (Mamboleo et al. 2023). Traditional journalistic tenets, such as objectivity and balance, also apply to science journalism (Mellor 2024). Hence, we may expect news writers with more science and technology background to be more objective in reporting emerging technologies, balancing discussions of benefits versus risks and new findings versus limitations in the stories, providing more substantive details, and overall refraining from exaggerating facts.

It is also possible, however, news writers with or without a science and technology background may not differ in whether they hype emerging technologies. Science is a very broad field: science reporters' specialization may be limited to a specific domain unrelated to a given news topic. Recent budget cuts to newsrooms have also resulted in the loss of specialized beat reporters, less training to help journalists gain new knowledge, and more reliance on scientists to contribute (Ashwell 2016; Menezes 2018). As we mentioned earlier, scientists, by serving as

sources in news or as direct contributors to columns, are motivated to hype their research for additional funding (Caulfield 2018; Intemann 2022; Soto-Sanfiel et al. 2025); journalists have to highlight the novelty and social impact of research, key elements of news value, to attract audience attention (Bednarek and Caple 2017). Consequently, science writers on online news outlets, regardless of their science background, may be apt to hype emerging technologies.

Hence, we propose another research question: *(RQ2) Do writers with and without science and technology background differ in how they discuss quantum science in online news stories, i.e., do they differ in their likelihood to (a) exaggerate, (b) mention benefits, (c) mention risks, (d) mention uncertainties, and (e) provide substantive content about quantum science?*

3 Methods

3.1 Data collection

On July 17, 2024, we used the search query "quantum AND science" in MediaCloud's database of "United States – National" to retrieve online news stories about quantum science in 2022 and 2023. We focused on these two recent years because three pioneering quantum scientists won the Nobel Prize in Physics in 2022, bringing more media and public attention to quantum science and technology (Billings 2022). MediaCloud is an open-source media content harvesting and analysis platform developed by Harvard University and the Massachusetts Institute of Technology; it is currently maintained by a consortium of universities and a media research nonprofit. MediaCloud allows users to access online news stories from a wide variety of curated lists. In our study, we used the "United States – National" collection, which included online news stories from 249 sources, including *The New York Times*, *CNN*, *Washington Post*, and a myriad of other online sites. MediaCloud has been used and analyzed in previous studies of media content (Kang et al. 2023).

We initially retrieved 2,523 news stories, a majority of which turned out to be related to artificial intelligence and other types of emerging technologies. As a result, we excluded all articles that did not contain "quantum" in the titles. From the remaining 389 articles, we further excluded film review articles that were completely irrelevant to quantum science, all press releases from a public relations newswire service, and paywalled articles. Ultimately, 192 online news articles were retained for further content coding.

3.2 Coding protocol

The two authors first reviewed and discussed some news stories in the sample to develop an initial codebook based on our conceptualization of media hype. We then independently coded the same set of 18 randomly selected news articles from the sample. We adopted a threshold of Krippendorff's α of 0.70 as satisfactory intercoder reliability (Krippendorff 2004). The intercoder reliability results based on these 18 stories were not satisfactory. We reviewed our coding results, discussed our differences and arrived at consensus codes for our disagreements. We also refined our codebook during this process. At our next phase, we embarked on a second round of pilot coding by independently analyzing another set of 25 randomly selected news articles. We achieved satisfactory intercoder reliability for all our variables except the acknowledgement of scientific uncertainties item. Similar to what we did before, we discussed and reached a consensus for our disagreements. Then, the two of us coded a third round of 29 randomly selected articles and achieved a satisfactory intercoder reliability rating for the acknowledgement of scientific uncertainties variable. Have established acceptable intercoder reliabilities for all the variables in our codebook, we then divided the rest of the sample for each one to code independently. The codebook can be found in the Appendix.

3.3 Operationalization of semantic media hype

We measured media hype using an objective corpus linguistic protocol with keyword matching and a subjective manual coding scheme. In their study, Millar et al. (2022) built a dictionary of 139 hype adjectives based on abstracts of projects supported by the National Institutes of Health published between 1985 and 2020 and examined the frequency of these words over time. An adjective was identified as hype if it could not be replaced with a more neutral word. Their study grouped hype words into 8 semantic categories: importance, novelty, rigor, scale, utility, quality, attitude, and problem.

There are two issues with this approach. First, an examination of the hype lexicon identified by Millar et al. (2022) shows that most words do not exaggerate facts, such as "scientific," "diverse," "broad," and "interdisciplinary." This operationalization provides a liberal, exaggerated estimate of the hype concept. Second, this simple corpus linguistic protocol does not capture the multi-dimensional features of hype proposed in our broad conceptual definition. To address these issues, we supplemented the keyword matching approach with manual content coding of additional story features. Our conceptualization of media hype specified three key features: exaggeration, benefit-risk imbalance, and simplification. Exaggeration was

identified by the presence of certain keywords curated from the extant literature and by the tone of the paragraph where these words appeared. Benefit-risk imbalance was studied by comparing mentions of benefits versus risks in stories. Simplification was operationalized as failure to address scientific uncertainties with quantum science or to provide substantive details regarding the topic. Hence, our coding examined the following features of hype: exaggeration, mention of benefits, mention of risks, acknowledgement of scientific uncertainties, and substantive details.

3.4 Coding scheme

Exaggeration. We coded if a news story presented a sensational or exaggerated picture of quantum science (0 = No, 1 = Yes; Krippendorff's α = 0.91). We took characteristics of hype language discussed in the literature as exemplary words to look for, such as "breakthrough" (Brown and Michael 2003; Roberson 2020), "revolution/revolutionary/revolutionize" (Brown and Michael 2003; Meyer et al. 2023), "exponential change" (Smith 2020), "supremacy" (Meyer et al. 2023), and "disruption" (Smith 2020). In our coding, a news article was considered as sensational or exaggerated if it contained these buzzwords and other similar descriptions (e.g., "historic breakthrough," "landmark discovery," "greatest ever," "transform/transformation," and "groundbreaking"). Note that out of these exemplary words, only "revolutionary" was included in Millar et al.'s (2022) lexicon. Our approach was similar to Dempster et al. (2022) who identified a similar set of buzzwords to capture sensationalism.

Mention of benefits. We coded if a news story addressed benefits, positive attributes, or advantages with quantum science and technology (0 = No mention of benefits, 1 = Mention of benefits; Krippendorff's α = 1).

Mention of risks. We coded if a news story addressed risks or concerns with quantum science and technology (0 = No mention of risks, 1 = Mention of risks; Krippendorff's α = 0.82).

Acknowledgement of scientific uncertainties. We coded if the news story included skeptical/critical/uncertain views toward quantum science and technology (0 = No, 1 = Yes; Krippendorff's α = 0.77).

Substantive details. We coded if a news story provided a simplified picture of quantum science and technology, or if it included substantive details (0 = Simplified coverage, 1 = mention of substantive details; Krippendorff's alpha = 0.71). Simplified stories tended to only mention quantum science and technology without providing enough background information or context on quantum science for the readers to grasp the subject matter. On the other hand, stories with substantive details had to not only mention critical quantum science concepts (e.g., qubit, entanglement,

superposition, etc.) but also sufficient explanations of these concepts for the readers to learn about quantum science or grasp the context of its impact.

In addition to coding for hype features, we also coded for the **background of the story writer**. We looked up the link to the bio to identify if the writer profile included "science," "technology," or showed clear evidence of expertise in science and technology. This way, we measured whether the writer was a general/non-science beat writer or a science and technology beat writer (0 = general/non-science beat writer, 1 = science and technology beat writer; Krippendorff's $\alpha = 1$).

4 Results

The frequencies of online news stories ($N = 192$) that fell into each coded category are reported in Table 1.

In response to RQ1, 15.63 % ($n = 30$) of the online news stories on quantum science exaggerated the topic, 76.56 % ($n = 147$) mentioned benefits, 24.48 % ($n = 47$) mentioned risks, 31.25 % ($n = 60$) included a critical or skeptical view of quantum science and technology that showed some uncertainties with science, and finally 56.25 % ($n = 108$) included substantive details.

Our narrow definition of semantic media hype focuses on the exaggeration of facts in news stories. To explore whether exaggerated ($n = 30$) versus non-exaggerated ($n = 162$) news stories about quantum science differed in other hype features, we conducted a series of χ^2 tests with Yate's continuity corrections due to

Table 1: Features of media hype about quantum science ($N = 192$).

Hype features		Total sample		Exag.		Non-Exag.		χ^2 tests	
		n	%	*n*	%	*n*	%	$\chi^2(1)$	*p*
Exaggeration	No	162	84.38						
	Yes	30	15.63						
Benefits	No	45	23.44	0	0	45	27.78	9.39	0.002
	Yes	147	76.56	30	100.00	117	72.22		
Risks	No	145	75.52	21	70.00	124	76.54	0.29	0.59
	Yes	47	24.48	9	30.00	38	23.46		
Uncertainties	No	132	68.75	18	60.00	114	70.37	0.83	0.36
	Yes	60	31.25	12	40.00	48	29.63		
Substantiveness	No	84	43.75	12	40.00	72	44.44	0.06	0.80
	Yes	108	56.25	18	60.00	90	55.56		

The χ^2 tests results reported above applied continuity correction due to some small cell sizes. Not applying continuity correction did not alter any of the substantive interpretations of the results by adopting the $\alpha < 0.05$ criterion.

some small cell sizes. But the substantive results (e.g., significance levels) did not change even without Yate's continuity corrections. We used an alpha level of 0.05 for all statistical tests. Results showed only one statistically significant difference: all exaggerated stories included discussion of benefits of quantum science while only 72.22 % of non-exaggerated stories did ($\chi^2(1, N = 192) = 9.39$, $p = 0.002$). These two types of stories did not differ in terms of how they mentioned risks ($\chi^2(1, N = 192) = 0.29$, $p = 0.59$), discussed uncertainties in science ($\chi^2(1, N = 192) = 0.83$, $p = 0.36$), or provided substantive details ($\chi^2(1, N = 192) = 0.06$, $p = 0.80$).

We also compared how often key characteristics of semantic hype co-occurred. In light of our conceptualization, we combined the presence of benefit mentions and the absence of risk mentions into a benefit-risk imbalance category and collapsed stories that failed to mention uncertainties of science and those that did not provide substantial details into a simplification category. Results show that 10.9 % ($n = 21$) included both exaggeration and benefit-risk imbalance features, 4.2 % ($n = 8$) included both exaggeration and simplification features, and 3.1 % ($n = 6$) included both benefit-risk imbalance and simplification features. Altogether, 3.1 % ($n = 6$) stories met all three criteria.

To address RQ2, additional χ^2 tests were conducted to compare how science versus non-science journalists/writers differed in how they discussed quantum science and technology. Additional results in Table 2 indicate that writers with science and technology background were indeed more likely to include substantive details about quantum science (63.77 % vs. 37.04 %, $\chi^2(1, N = 192) = 11.20$, $p = 0.001$) than writers without such background. However, these two types of writers did not differ

Table 2: Media hype features and story writer background ($N = 192$).

Hype features		Science writer		Non-science writer		χ^2 tests	
		n	%	*n*	%	$\chi^2(1)$	*p*
Exaggeration	No	119	86.23	43	79.63	0.83	0.36
	Yes	19	13.77	11	20.37		
Benefits	No	36	26.09	9	16.67	1.43	0.23
	Yes	102	73.91	45	83.33		
Risks	No	103	74.64	42	77.78	0.07	0.79
	Yes	35	25.36	12	22.22		
Uncertainties	No	92	66.67	40	74.07	0.68	0.41
	Yes	46	33.33	14	25.93		
Substantiveness	No	50	36.23	34	62.96	11.20	0.001
	Yes	88	63.77	20	37.04		

The χ^2 tests results reported above applied continuity correction due to some small cell sizes. Not applying continuity correction did not alter any of the substantive interpretations of the results by adopting the $\alpha < 0.05$ criterion.

in how they exaggerated quantum science (13.77 % vs. 20.37 %, $\chi^2(1, N = 192) = 0.83$, $p = 0.36$), mentioned benefits (73.91 % vs. 83.33 %, $\chi^2(1, N = 192) = 1.43$, $p = 0.23$), mentioned risks (25.36 % vs. 22.22 %, $\chi^2(1, N = 192) = 0.07$, $p = 0.79$), or addressed uncertainties in science (33.33 % vs. 25.93 %, $\chi^2(1, N = 192) = 0.68$, $p = 0.41$).[1]

5 Discussion

This project aims to examine the scope of semantic hype in online stories about quantum science on top US news websites via a content analysis study. We have proposed a narrow definition of semantic media hype that focuses on exaggeration and a broad definition that encompasses three defining characteristics, including exaggerating science, overstating benefits while downplaying risks, and simplifying sophisticated scientific topics. We have offered more clarity and consistency to the fragmented literature on the conceptualization and operationalization of media hype.

Our content analysis revealed that only 15.63 % of online quantum science news stories engaged in exaggeration and sensationalism by using superlative (e.g., "greatest ever") or grandiose (e.g. "historic breakthrough") phrases. Most of such language appeared either in the headlines or the leads, which is unsurprising because sensationalism in headlines and leads attracts attention. For instance, the lead of a *Quartz* story included multiple instances of exaggerating the impact of quantum computing by speculating on the unknown future: "In science fiction, quantum computing is often the magic behind time travel machines or alternate universes. But in real life, it could be the next big thing in computing; the end of cryptography as we know it; the catalyst for revolution in industries as diverse as finance, medicine, and more." (Teng 2022).

The percentage of exaggerated stories identified in our dataset is largely in line with what was reported in the literature. For comparison, Bubela and Caulfield (2004) reported that between 11 % and 26 % of genetic research news stories included some degrees of hype. This suggests that exaggeration likely does not make up the majority of news coverage on emerging technologies.

However, with our broad definition of sematic media hype, we found more online news stories with hype features. We found that quantum science stories in online media were more likely to employ a benefit frame (76.56 %) than a risk frame (24.48 %). While these stories mentioned a wide variety of positive social and

1 We also compared the presence of hype features in science versus non-science publications at the suggestions of a reviewer. None of the differences for the five hype features was statistically significant. Results are reported in the Supplemental Material.

economic implications of quantum technologies for drug discovery, sustainability, finance and so forth, most of the risk discussions focused on quantum computing's threat to cybersecurity when it would render current cryptography obsolete and vulnerable to attacks. This benefit-risk imbalance is congruent with the current weight of the literature on benefit-risk framing of emerging technologies (Liu et al. 2022). It is also evidence of techno-optimism – in this case quantum optimism (Hjörleifsson et al. 2008). Even though risks are not given as much attention as benefits at this nascent phase of quantum science development, media coverage can become more critical as emerging technologies mature. Of note, the percent of risk-framed stories in our sample was still higher than the 5 %–15 % range identified in Bubela and Caulfield's (2004) analysis of genetic research coverage; moreover, the percent of benefit-framed stories in our study was lackluster compared to the 97 % figure reported in Bubela and Caulfield's research. This implies a rather modest form of techno-optimism, far from the extreme case of techno-utopianism, in online media coverage of quantum science. This could mean that quantum science and technology may indeed pose more risks than other emerging technologies. It could also be that the outlets covering quantum science in our study were more alarmed by the consequences of these cybersecurity threats or that the public became increasingly concerned about privacy and security of emerging technologies, including Generative Artificial Intelligence (Deloitte 2024), potentially augmenting the weight of the risk frame in covering emerging technologies.

We want to stress that we are not making a normative claim here that it is wrong for the mass media to focus more on benefits than risks of an emerging technology. There is currently no clear scientific consensus or understanding of the benefits and risks of the emerging quantum technology. As a matter of fact, one can make the argument that quantum science may indeed bring more benefits than risks. Although balance of perspectives in news reporting has been a common journalistic norm (Westerstahl 1983), this practice has been subjected to increasing criticism and debate. Expecting the mass media to provide a balanced coverage of benefits and risks of an emerging technology may in fact create a false balance, which we do not endorse. Decades of research in environmental communication has revealed that improperly balancing the climate change debate against the weight of scientific evidence can mislead public opinion (Boykoff and Boykoff 2004). An important benchmark here is scientific consensus, the extent to which scientific experts agree upon the weight of benefits compared to risks. In the context of climate change communication, perceived scientific consensus is a gateway belief to people's attitudes toward climate change and support for mitigation measures (van der Linden 2021). No work that we are aware of has measured scientific consensus on the social impact of quantum technology, an important area for future research. Only then will we be able to judge whether the current benefit-risk imbalance might be warranted.

We also argued that simplification was another feature of media hype and it could be manifested as failure to acknowledge scientific uncertainties or to provide substantial details on scientific research. However, our review of the recent literature showed increasing advocacy for emerging science communication norms to address these two issues (Brüggemann et al. 2020). Our study revealed an noteworthy finding: while the majority of quantum science stories (68.75 %) failed to address uncertainties with quantum science research, more than half (56.25 %) did provide substantive details. Our results echo findings from prior studies that showed science news on personalized medicine and genetic research also avoided discussing scientific uncertainties (Caulfield and Bubela 2004; Marcon et al. 2018). While not acknowledging uncertainties may solidify public support for quantum science, it can also create several challenges, such as setting unrealistic optimistic expectations; hence this feature and the benefit-risk imbalance can reinforce each other, creating an escalating spiral of inflated expectations and techno-optimism. This concern has been expressed by multiple scholars who worry that when such expectations are not met, trust and support will suffer (Intemann 2022; Master and Resnik 2013). Granted, discussing uncertainties can also come with a cost: adding complexities to news stories may diminish engagement and do more harm (Osman et al. 2018). As a result, science journalists and communicators face a dilemma: to hold onto the traditional science communication norm of simplicity or the emerging norm of transparency and interpretation. One solution can be to integrate scientific uncertainty into science literacy training for the public so that the audience will be more competent in interpreting uncertainties in science news (Beets et al. 2025).

Encouragingly, over half of the quantum science and technology stories (56.25 %) included substantive details. Simplified stories in our sample tended to (1) highlight a certain news value without the need to delve into the details of quantum science research (e.g., multiple stories announcing three quantum scientists winning the 2022 Nobel Prize in Physics), (2) assume the readers had prior knowledge of quantum science (e.g., a *Forbes* story penned by a CEO of a quantum software company discussing 12 industries affected by quantum computing), or (3) speculate on a society in the future impacted by quantum science (e.g., an article in *The Conversation* discussing what quantum technology would mean for Canada's future). On the other hand, stories with substance tended to elaborate upon fundamental concepts in quantum science, such as qubit and entanglement, and provide more contextual information about research studies. For instance, a story that appeared in *Live Science*, a popular science media outlet, covered a new research study about detecting a charm quark in protons through a quantum physics experiment (Peppas 2022). This story provided detailed explanations of critical science concepts (e.g.,

protons, charm quarks, and principles of quantum physics) as well as the research process (e.g., experimental facility and data analysis method) so that a lay reader can still make sense of the scientific discovery in a proper context. Of note, the writer also acknowledged scientific uncertainties by stating that "The level of evidence wasn't high enough for the researchers to declare the undeniable discovery of the charm quark in protons" and that "for now, physicists still need more data on the elusive 'charm' within a proton" (Peppas 2022).

The high proportion of stories with substantive and contextual details suggests that some emerging science communication norms, such as knowledge journalism (Brüggemann et al. 2020) and justification reporting (Gelfert and Schneider 2025), may be at play already. However, what we have observed in this study may also be domain specific. Since quantum technology is an obscure subject to the lay public, more background and contextual information may be needed in a news story so that the audience can grasp the social and personal implications of this technology. Our emphasis on the substantiveness dimension of hype, to a great extent, presumes the deficit model (Akin and Scheufele 2017) or the science literacy model (Secko et al. 2013) of public understanding of science where communication mostly goes one way from experts to the public who is presumed to lack sufficient knowledge on a topic. We observed that most news stories with substantive details indeed were representative of the deficit model where the stories were educational but lacked engagement.

Since exaggeration is the most frequently mentioned feature in the discursive hype literature, we also compared if benefit-risk imbalance and simplification, identified in our broad definition of hype, differed between exaggerated and non-exaggerated stories. Of note, the only significant difference concerned the presence of the benefit frame: all the exaggerated stories mentioned benefits while only 72 % of non-exaggerated stories did. In other words, exaggeration always involved mentioning benefits in our sample of stories. The reverse was not necessarily true though: not all benefit-framed stories exaggerated quantum science. When we examined the co-occurrence of the three key features of hype, exaggeration and benefit-risk imbalance features were more likely to occur together than other pairs. However, we found only a small percent of stories (3.1 %) to include all hype features. Hence, a conservative estimate of hype, assuming the presence of all hype features, suggests that blatant hype was quite rare in online media stories about quantum science.

Next, we examined whether news writers' science background made a difference for the presence of hype features. We found that 71.88 % of the writers had science and technology background, many of whom even had training in quantum science. This echoes the growing concern that budget cuts have led to inadequate training of general-beat journalists and more reliance on scientists (Ashwell 2016;

Menezes 2018). One positive outcome of this trend can be more informative science stories since our finding shows that writers with more science background were more likely to provide substantive details than those without science background. As a matter of fact, this was the only statistically significant difference between these two groups of writers. As post-hoc analysis, we also examined whether the scientists quoted in the stories exaggerated quantum science, and we did not find any such quotes, even amongst those we classified as exaggerated stories. These results contradicted the concerns expressed by some scholars that scientists hype their research by serving as sources in news or as direct contributors, at least not more likely than general-beat reporters (Caulfield 2018; Intemann 2022; Soto-Sanfiel et al. 2025). It appears that journalists quote scientists to provide substantive explanations that enhance the credibility of the articles rather than for sensational effect (Schipani 2024). The difference in providing substantive details between scientists and general-beat reporters also suggests that continued, professional training in emerging science topics is critical in bringing more depth to science stories online. On the other hand, the lack of significant differences in how these two groups of writers exaggerated science, mentioned benefits and risks, or discussed scientific uncertainties may also be indicative of an emerging post-normal science communication pattern where roles, norms and practices of scientists and journalists are converging (Brüggemann et al. 2020).

In addition to comparing news writers with science versus non-science background, we also examined hype features in science versus non-science publications in post-hoc analysis, only to find no significant statistical differences. In terms of hype features, it appears that science reporting is of similar quality in both science and non-science online media outlets. This may be attributed to the fact that quantum science is a specialized, technical field. As a result, news writers as well as readers of quantum science stories share similar background and interest in science and no-science publications.

In this paper, we have stressed the significance of acknowledging scientific uncertainties and limitations in research. Similarly, findings from this study should be interpreted with some caveats in mind. First, our sample only included US online news outlets indexed by MediaCloud. Certain business (e.g. *Forbes* and *Fortune*) and science/technology (e.g., *Quartz* and *TechCrunch*) media were overrepresented in our sample. The results may change if a different news database is used. We also excluded paywalled articles from our analysis because they were not open to free public access, presenting a financial barrier for readers and our research team. Admittedly, these articles might be of higher quality and less likely to hype emerging technologies, thereby potentially introducing another source of sampling bias. However, paywalled articles constituted a small part of our sample (about 5 %) and most were local news sites (e.g., *The Baltimore Sun* and

The Orange County Register). The peculiar characteristics of our sample also suggest that future research can examine if our results will hold in other contexts, such as a different emerging technologies (e.g., artificial intelligence), media coverage in another country, a timeline beyond the two years covered in this study (i.e., 2022 and 2023), and coverage in other types of media (e.g., social media). Second, we used a conservative operationalization to measure exaggeration in this study, compared to Millar et al. (2022). It is open to debate as to whether our keyword-based coding approach effectively captured exaggeration. Some lexicons used in the literature are too all-encompassing while others are too restrictive. Results could have differed widely by different operationalizations. Future research can compare levels of exaggeration employing different operationalization approaches. Third, we employed binary categories (Yes or No) to code the presence of hype features, but some of these features may be multi-dimensional. Take scientific uncertainty for instance. The extant literature has suggested multiple types, such as deficient, technical, scientific, and consensus uncertainties (Gustafson and Rice 2019; Guo et al. 2025). Future research can specify whether emerging science news addressed any of these uncertainty types. In addition, results from this content analysis should not be extrapolated to conclusions about media effects. Our analysis only investigated how quantum science was portrayed on online media; our study did not imply that the public indeed believed media hype of quantum science or that the public believed quantum science had more benefits than risks. To tackle these questions, future researchers are encouraged to study the effects of online media coverage of quantum science using an experimental design. Some critical consequences to investigate can include emotional reactions, trust, and support for quantum science. Take trust for instance. The extant literature has hinted that hype can inflate public expectations about emerging technologies, but when such expectations are not met, trust will suffer (Intemann 2022; Master and Resnik 2013). To the best of our knowledge, this proposition has not been empirically tested. Last, as we mentioned earlier in the discussion, future research can examine the scientific consensus on the social benefits and risks of quantum science so that we will be able to judge whether current media coverage of benefits and risks is adequate.

Taken together, this paper has significant theoretical and practical implications. On the theoretical front, it offers a multi-dimensional conceptualization and operationalization of semantic media hype, stimulating more research into the nuances of various aspects of media hype. On the practical front, this paper reveals some presence of media hype regarding quantum science reporting. Ultimately, media

hype of emerging technologies should be studied within the dual context of news production and normative considerations in science communication.

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Appendix
Media hype of quantum science codebook

Part I. Metadata

Q1. Who is coding?
Q2. What is the name of the media outlet?
Q3. What is the publication year? Write in this format: XXXX.
Q4. What is the publication month? Write in numerical format: XX
Q5. What is the publication day of the month? Write in this format: XX.
Q6. What is the word count of the article body, including boilerplate language?
Q7. What type does the article represent?
    1. 1. News report/feature
    2. 2. Opinion/column/commentary/letter
    3. 3. Interview
    4. 4. Review of a product or announcement of an upcoming event
    5. 5. Other
Q8. What type of journalist is the writer?
    1. 1. General beat reporter/contributor or non-science/tech reporter/contributor
    2. 2. Science and technology beat reporter or scientist (the public profile includes "science" or "technology")
    3. 3. Others, such as un-identified

Part II. Content

Q9. Does the news story present a sensational or exaggerated picture of quantum science and engineering for audience attention or emotional reactions? A news story article is considered sensational or exaggerated if it contains such buzzwords as "historic breakthrough," "landmark discovery," "greatest ever," "revolutionize/revolution," "transform/transformation," or "groundbreaking."
   0. No
   1. Yes

Q10. Does the news story address benefits, positive attributes, or advantages with quantum science and engineering?
   0. No mention of benefits
   1. Mention of benefits

Q11. Does the news story address risks or concerns with quantum science and engineering?
   0. No mention of risks
   1. Mention of risks

Q12. Does the news story include skeptical/critical/uncertain views toward quantum science and engineering?
   0. No
   1. Yes

Q13. Does the news story provide a simplified picture of quantum science and engineering, or does it include substantial substance to quantum science and engineering?
   0. Simplified picture
   1. With substance

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