

HOW DO PEOPLE FEEL ABOUT COVID-19 VACCINE? AN ANALYSIS OF TWITTER POLARIZATION

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Abstract

This study investigates the polarization of public sentiment on Twitter concerning COVID-19 vaccines versus traditional vaccines, analyzing discourse from 2015 to 2021. Utilizing Linguistic Inquiry and Word Count (LIWC) analysis on a large dataset of tweets, we find significantly more positive sentiment and expressions of collective achievement associated with COVID-19 vaccines compared to traditional vaccines, which conversely elicited higher negative sentiment, risk perception, and death-related discourse. These findings challenge prevailing narratives of generalized vaccine hesitancy, suggesting a distinct affective response to COVID-19 vaccines. We attribute this divergence to a confluence of factors, including the unique psychological context of the pandemic (e.g., rallying effects, anxiety management), demographic characteristics of platform users (e.g., optimism bias among younger cohorts), the influence of selective exposure within online environments, and perceptions shaped by the rapid vaccine development process. The results underscore the critical need for nuanced, context-specific public health communication strategies tailored to address the distinct factors shaping risk-benefit perceptions for different vaccine types within diverse online communities.

Keywords: Vaccine, Covid-19, Polarization.

INTRODUCTION

The COVID-19 pandemic profoundly reshaped global health communication, establishing social media platforms like Twitter as pivotal arenas for information dissemination and health behavior formation (Sousa et al., 2020; WHO, 2021). These platforms became critical yet complex spaces for promoting vaccine acceptance amidst rapid information flow and concurrent misinformation. While

existing research documents social media's influence on general vaccine attitudes (Larson et al., 2014; Bail et al., 2018; Johnson et al., 2020), a significant gap exists in the comparative analysis of public sentiment towards COVID-19 vaccines versus traditional vaccines. Prior studies often neglect the unique socio-political and psychological context of the COVID-19 pandemic—including accelerated vaccine development, intense media focus, and a global crisis mentality—which may differentially shape public perception compared to established vaccines.

This study directly addresses this gap, recognizing that understanding these sentiment differences is crucial. The pandemic's unique "infodemic" necessitates specific investigation. Differentiating sentiments can reveal distinct drivers of hesitancy and acceptance for COVID-19 vaccines, enabling targeted interventions and tailored counter-misinformation strategies. Furthermore, this comparative analysis offers vital knowledge for future pandemic preparedness.

To investigate this research gap, we employ a framework integrating Selective Exposure Theory (Stroud, 2014) to analyze how pre-existing beliefs shape online information consumption; Optimism Bias (Sharot, 2011) to interpret potential demographic influences on risk perception; and Anxiety-Uncertainty Management Theory (Gudykunst, 2005) to explore positive vaccine sentiment as a coping mechanism. Analyzing Twitter data from 2015-2021, this study aims to: (i) quantify and compare sentiment towards COVID-19 and traditional vaccines; (ii) identify associated themes and narratives; (iii) investigate influencing factors like demographics and misinformation; and (iv) offer evidence-based recommendations for public health communication. This research contributes a nuanced comparative understanding of online vaccine discourse, providing critical insights for navigating social media's complex information environment to promote informed vaccination decisions.

THEORETICAL REVIEW

The COVID-19 pandemic precipitated a profound shift in the interplay between public sentiment, health communication, and digital platforms, elevating spaces like Twitter to central roles in shaping perceptions and responses, particularly concerning vaccination (Sousa et al., 2020; WHO, 2021). This necessitates a rigorous theoretical understanding of sentiment dynamics—formation, diffusion, polarization—within online networks, especially regarding vaccine uptake. Critically, existing research often overlooks the unique contextual factors of the COVID-19 pandemic that may differentially influence public sentiment compared to traditional vaccines, representing a significant research gap.

Online discourse is increasingly characterized by opinion polarization, where individuals gravitate towards ideologically aligned groups, reinforcing beliefs and societal divisions (Garimella & Weber, 2017; Walter et al., 2020). This is amplified by social media algorithms fostering "echo chambers" that limit exposure to diverse perspectives (Bakshy et al., 2015; Lazer et al., 2018; Pariser, 2011), potentially entrenching vaccine stances and impeding informed decision-making. Selective Exposure Theory (Stroud, 2014), positing a preference for belief-confirming information, is directly relevant to understanding these dynamics, though its operation may differ between novel pandemic contexts and established vaccination campaigns.

Vaccine hesitancy, identified as a paramount global health threat (WHO, 2021), is significantly exacerbated by social media misinformation (O'Connor & Murphy, 2020; Pennycook et al., 2020; Sharma et al., 2021). Understanding the sources, propagation, and impact of misinformation is crucial, particularly as narratives surrounding novel COVID-19 vaccines may differ substantially from those concerning traditional ones. Furthermore, social media influencers wield considerable influence over vaccination opinions (Henkel et al., 2023; Troiano & Nardi, 2021), necessitating comparative analysis of their impact on perceptions of different vaccine types to inform effective communication strategies.

Navigating these complexities requires advanced analytical approaches. This study leverages big data analytics, particularly sentiment analysis (Xie et al., 2023; Tausczik & Pennebaker, 2010), to gain a granular understanding of vaccine discourse dynamics on platforms like Twitter. Analyzing large-scale datasets allows for nuanced pattern identification, misinformation tracking, and assessment of key opinion leader influence, enabling a direct comparison between COVID-19 and traditional vaccine sentiment trajectories to address the core research gap and inform evidence-based communication.

Incorporating psychological frameworks, such as Optimism Bias (Sharot, 2011) for risk perception and Anxiety-Uncertainty Management Theory (Gudykunst, 2005) for information processing under uncertainty, offers further insight. However, the applicability of these theories to the distinct contexts of COVID-19 versus traditional vaccines requires the empirical investigation undertaken in this study.

Understanding Sentiment Analysis

Sentiment analysis, or opinion mining, is a critical computational linguistics subfield providing insights into public attitudes across diverse domains (Liu, 2012; Pang & Lee, 2008). Its significance is pronounced in public health, where understanding sentiment towards vaccination campaigns is vital for refining communication strategies and improving uptake (Aslan et al., 2023; Tausczik & Pennebaker, 2010; Larson et al., 2018). Particularly within the COVID-19 context, sentiment analysis offers a crucial methodology for discerning perceptual differences between novel and traditional vaccines, thereby addressing this study's core research gap.

Social media platforms like Twitter offer rich, real-time data for sentiment analysis, serving as valuable resources for gauging public opinion on evolving issues like vaccination (Aslan et al., 2023; Garimella & Weber, 2017; Mejova et al., 2015), despite inherent limitations such as potential demographic biases and inauthentic activity, which are addressed methodologically. Accurately extracting sentiment from text remains challenging due to linguistic nuances like sarcasm and idioms (Hutto & Gilbert, 2014; Wilson, Wiebe & Hoffmann, 2005). However, advancements in machine learning (ML) and natural language processing (NLP) have significantly enhanced accuracy, enabling analysis of complex linguistic patterns and contextual cues (Yadav & Vishwakarma, 2020; Zhang, Ghosh, Dekhil, Hsu & Liu, 2011) for a granular understanding across demographics (Chung & Pennebaker, 2013; Pennycook et al., 2020). These integrated techniques allow precise extraction of sentiment polarity and intensity within broader socio-political contexts, providing data-driven insights for targeted public health interventions (Thelwall et al., 2010; O'Connor & Murphy, 2020; Xie et al., 2023; Vijayaraghavan et al., 2016).

Within this landscape, the Linguistic Inquiry and Word Count (LIWC) program (Pennebaker et al., 2015) is a widely validated tool for investigating psychological and social dimensions of language use, including polarization on platforms like Twitter. LIWC quantifies emotional, cognitive, and structural language components, detecting latent psychological states and providing a nuanced understanding of vaccine discourse complexities (Tausczik & Pennebaker, 2010; Chung & Pennebaker, 2013; Cohn, Mehl & Pennebaker, 2004). Its ability to quantify subtle linguistic cues makes it particularly well-suited for investigating perceptual differences between COVID-19 and traditional vaccines. Analyzing tweets with LIWC enables quantitative assessment and comparison of sentiment polarization by measuring variables like emotional tone and cognitive complexity. This facilitates a fine-grained understanding of expressed attitudes towards vaccination, revealing language patterns indicative of polarized views and underlying psycho-social drivers differentiating COVID-19 from traditional vaccine discourse (Tausczik & Pennebaker, 2010; Henkel et al., 2023). LIWC can further aid in identifying linguistic markers of misinformation.

Polarization on Twitter and COVID-19 Vaccines

Discourse surrounding COVID-19 vaccines on Twitter became a key analytical focus, reflecting broader societal divisions ranging from support to skepticism and denial (Allington et al., 2021; Loomba et al., 2021). This platform serves as a microcosm where observed polarization stems from a complex interplay of factors including misinformation, political ideologies, personal experiences, and amplification by influencers (Henkel et al., 2023; Dolman et al., 2023; Xie et al., 2023; Muric, et al., 2021). Crucially, this polarization may manifest differently for COVID-19 vaccines compared to traditional ones due to the pandemic's unique socio-political context.

Misinformation proliferation is a significant driver of vaccine-related polarization (Roozenbeek et al., 2020; Loomba et al., 2021). Social media design can facilitate echo chambers and filter bubbles, reinforcing pre-existing beliefs and hindering constructive dialogue (Garimella & Weber, 2017; Lazer et al., 2018; Cinelli et al., 2021). Algorithmic content curation, often prioritizing engagement, may

inadvertently amplify sensational or inaccurate content, further entrenching polarized views (Bakshy et al., 2015; Eady et al., 2023).

Mitigating this online polarization is a public health imperative. Vaccine hesitancy is a top global health threat (WHO, 2021), demanding multifaceted approaches to foster acceptance and combat misinformation (Larson et al., 2014; Dubé et al., 2013). Conversely, positive sentiment amplified by trusted sources and influencers can promote uptake and confidence (Lin et al., 2020; Attwell et al., 2021). Leveraging influencers effectively is critical for health communication (Garimella & Weber, 2017; Troiano & Nardi, 2021).

Sentiment analysis of Twitter data offers a valuable method for understanding public perceptions regarding COVID-19 vaccines, providing actionable insights for targeted communication strategies (Hussain et al., 2021). Theoretical frameworks like the Spiral of Silence (Noelle-Neumann, 1974), suggesting minority opinions are less likely to be expressed, and Social Identity Theory (Tajfel & Turner, 1979), highlighting group identification's role in opinion formation, offer lenses to understand polarization drivers. However, their specific applicability in comparing COVID-19 and traditional vaccine discourse requires empirical investigation, as undertaken here.

Leveraging big data analytics, including sentiment analysis, is crucial for navigating the complex public opinion landscape. These tools enable a nuanced understanding of sentiment-shaping factors, empowering authorities to devise effective interventions against hesitancy and misinformation, considering online discourse characteristics (O'Connor & Murphy, 2020; Pennycook et al., 2020; Vraga & Bode, 2020). Systematically exploring COVID-19 vaccine polarization on social media is thus essential. Integrating sentiment analysis insights with theory facilitates nuanced, evidence-based strategies to enhance engagement, counter misinformation, and improve public health. This research contributes through its comparative analysis of polarization dynamics surrounding COVID-19 versus traditional vaccines.

Comparative Sentiment Analysis: Hypotheses

The emergence of COVID-19 vaccines coincided with notably high positive online sentiment, potentially interpretable via the "rallying 'round the flag" effect common during crises (Mueller, 1970). This effect, involving increased cohesion against a common threat, was likely amplified by the pandemic's global urgency and highly publicized collaborative vaccine development efforts (Van Bavel et al., 2020; Lazarus et al., 2021). Consequently, COVID-19 vaccines were framed not just as medical tools but as symbols of scientific progress and resilience, a narrative reinforced by public health communications and endorsements, potentially increasing acceptance (Pennycook et al., 2020; Van Bavel et al., 2020; Bokemper et al., 2021).

Conversely, historical discourse on traditional vaccines often features persistent skepticism, fueled by misinformation and amplified within online echo chambers (Wilson & Wiysonge, 2020; Johnson et al., 2020). This sentiment divergence may stem from interacting factors: the novelty of COVID-19 vaccines and the pandemic's immediate threat possibly overshadowed prior hesitancy, while extensive positive media coverage contrasted with often negative portrayals of traditional vaccines. Based on this, we propose:

H1: Positive affect, as expressed in tweets, will be significantly higher in discussions related to COVID-19 vaccines compared to discussions related to traditional vaccines.

H2: Negative affect, as expressed in tweets, will be significantly higher in discussions related to traditional vaccines compared to discussions related to COVID-19 vaccines.

The collective effort against the pandemic fostered a sense of shared purpose, aligning with Collective Effervescence (Durkheim, 1912), where shared action towards common goals enhances cohesion and emotional states. Rapid COVID-19 vaccine development was widely seen as a collective victory, potentially boosting public sentiments of achievement and efficacy (Kahneman, 2011; Bandura, 1997). This leads to:

H3: Expressions of achievement-related sentiments, as identified in tweets, will be significantly more pronounced in discussions related to COVID-19 vaccines compared to discussions related to traditional vaccines.

Risk perception critically influences vaccination decisions. Traditional vaccine risk perception is partly shaped by cognitive biases and misinformation, potentially exaggerating adverse effect concerns (Slovic, 1987; Larson et al., 2018). In contrast, the salient COVID-19 threat may have recalibrated risk-benefit analyses towards vaccination, prioritizing protection over potential, less publicized vaccine risks (Betsch, Böhm, & Chapman, 2015; Brewer et al., 2007). This suggests:

H4: Expressions of risk perception, as identified in tweets, will be significantly higher in discussions related to traditional vaccines compared to discussions related to COVID-19 vaccines.

Finally, vaccine-related death perceptions are susceptible to the availability heuristic (Tversky & Kahneman, 1973), where publicized rare events disproportionately increase fear. For COVID-19 vaccines, dominant messaging emphasized prevention of severe illness and death, potentially mitigating mortality anxieties (WHO, 2021; Oliver et al., 2021). This contrasts with traditional vaccine discourse where controversies might heighten perceived death risk. Therefore:

H5: Expressions related to death, as identified in tweets, will be significantly more prevalent in discussions about traditional vaccines than in discussions about COVID-19 vaccines.

Together, these hypotheses posit a complex interplay of factors shaping sentiment towards different vaccine types, focusing on contrasting COVID-19 and traditional vaccine perceptions. Investigating these hypotheses offers insights into online vaccine discourse dynamics, informing more effective public health communication strategies.

METHODOLOGY

To investigate the intricate dynamics of public sentiment towards traditional and COVID-19 vaccines, this study employed a mixed-methods approach, combining quantitative sentiment analysis with qualitative contextual interpretation. This approach was designed to capture the nuanced distinctions in online discourse and address the research hypotheses outlined in Section 4. The methodology is structured as follows:

Data Collection

We utilized the R statistical programming environment (R Core Team, 2023) in conjunction with the *rtweet* package (Kearney, 2019) to systematically extract publicly available Twitter data. Data collection was guided by a carefully curated set of keywords. For traditional vaccines, the keywords included: #vaccine, vaccine, Vaccines, and #vaccines. For COVID-19 vaccines, a broader set of keywords was employed to encompass the evolving terminology used during the pandemic: "COVID-19 vaccination", "coronavirus vaccination", "COVID vaccine", "COVID-19 vaccine", and variations thereof. This dual-pronged approach ensured comprehensive coverage of both vaccine categories. The data collection period spanned from January 2015 to December 2021, encompassing both pre-pandemic and pandemic periods, enabling a comparative analysis of sentiment trends over time. To mitigate potential confounding factors and ensure linguistic consistency, the analysis was restricted to English-language tweets. Furthermore, tweets were geolocated to major English-speaking regions (e.g., United States, United Kingdom, Canada, Australia) using Twitter's API metadata, where available, to account for potential geographical variations in sentiment. The analyzed tweets originated from a diverse range of user accounts, including individuals, health institutions, governmental organizations, news media, and other entities.

Textual Analysis and Sentiment Scoring

For textual analysis, we employed the Linguistic Inquiry and Word Count (LIWC) software (Pennebaker et al., 2015), a widely validated and reliable tool for quantifying the emotional, cognitive, and structural components of written and spoken language (Tausczik & Pennebaker, 2010). LIWC's robust analytical framework is particularly well-suited for dissecting the complex tapestry of sentiments associated with vaccine discourse on Twitter, allowing for the identification of subtle linguistic cues associated with psychological states. LIWC operates by comparing each word in a given text against a predefined dictionary of word categories, generating scores that represent the percentage

of words in the text belonging to each category. For this study, we focused on LIWC categories relevant to our hypotheses, including: Positive Emotion, Negative Emotion, Achievement, Risk, and Death.

To quantify differences in sentiment scores across the two vaccine categories (COVID-19 and traditional) and across time, we applied Analysis of Variance (ANOVA) (Field, 2013), a robust statistical method for comparing means between two or more groups. Specifically, we used a two-way ANOVA, with vaccine type (COVID-19 vs. traditional) and time period (pre-pandemic vs. pandemic) as independent variables, and the LIWC sentiment scores as dependent variables. Post-hoc tests (Tukey's HSD) were conducted to identify specific pairwise differences where significant main effects or interactions were found. Statistical significance was set at $p < 0.05$.

This study adhered to all relevant ethical guidelines. Data collection was limited to publicly available tweets, and no personally identifiable information was collected or stored. The analysis focused on aggregate sentiment trends and did not involve identifying or targeting individual users. The study was conducted in accordance with Twitter's terms of service.

This rigorous methodological approach, combining strategic data collection, robust textual analysis, and appropriate statistical techniques, is designed to provide a comprehensive and nuanced understanding of the sentiments surrounding traditional and COVID-19 vaccines on Twitter. By explicitly addressing potential biases and limitations, and by grounding the analysis in established theoretical frameworks (as detailed in Sections 2 and 3), this study aims to contribute substantively to the broader academic discourse on vaccination, public sentiment, and the role of digital platforms in health communication.

FINDINGS AND DISCUSSION

Our investigation into the dynamics of public sentiment towards COVID-19 and traditional vaccines on Twitter yielded compelling findings. Employing ANOVA analysis, we examined a comprehensive dataset of tweets spanning from January 2015 to December 2021, encompassing both pre-pandemic and pandemic periods. This analysis unveiled significant disparities in the emotional tenor of online discourse surrounding these two vaccine categories.

Contrary to the prevailing narrative of widespread vaccine hesitancy, our analysis revealed a significantly higher level of positive sentiment in tweets concerning COVID-19 vaccines compared to those discussing traditional vaccines. Specifically, COVID-19 vaccine-related tweets exhibited an average positive sentiment score of 0.65, while traditional vaccine-related tweets registered a score of 0.45 ($p < 0.01$). This disparity in positive affect aligns with observations of a "rallying effect" during crises, where communities often demonstrate heightened solidarity and optimism in response to collective threats (Van Bavel et al., 2020). The unprecedented global focus on COVID-19 vaccine development, coupled with the pervasive desire for a return to normalcy, may have fostered a uniquely positive sentiment towards these vaccines.

Conversely, our analysis indicated a heightened prevalence of negative sentiment in tweets concerning traditional vaccines. Traditional vaccines garnered a negative sentiment score of 0.60, compared to 0.35 for COVID-19 vaccines ($p < 0.01$). This finding resonates with existing literature that documents the persistence of vaccine hesitancy and the enduring impact of misinformation, which has historically eroded public trust in vaccines (Loomba et al., 2021). The skepticism and apprehension that have long surrounded traditional vaccines underscore the challenges in dispelling deeply ingrained misconceptions and anxieties (Wilson & Wiysonge, 2020).

These divergent emotional responses highlight the imperative for nuanced and targeted public health communication strategies. The predominantly positive reception of COVID-19 vaccines presents a valuable opportunity to leverage this sentiment and promote broader vaccine acceptance. Conversely, the negativity surrounding traditional vaccines necessitates renewed efforts to combat misinformation and enhance vaccine literacy, particularly in the context of emerging infectious diseases and future vaccination campaigns (Eysenbach, 2020; Larson, 2020).

By understanding the distinct emotional landscapes associated with different vaccine types, public health communicators can tailor their messages to resonate with specific audiences and address their unique concerns. This approach may involve emphasizing the collective benefits of vaccination,

highlighting scientific evidence, and countering misinformation narratives. Furthermore, recognizing the potential influence of social media dynamics, such as the role of influencers and the spread of misinformation, is crucial for developing effective communication strategies in the digital age.

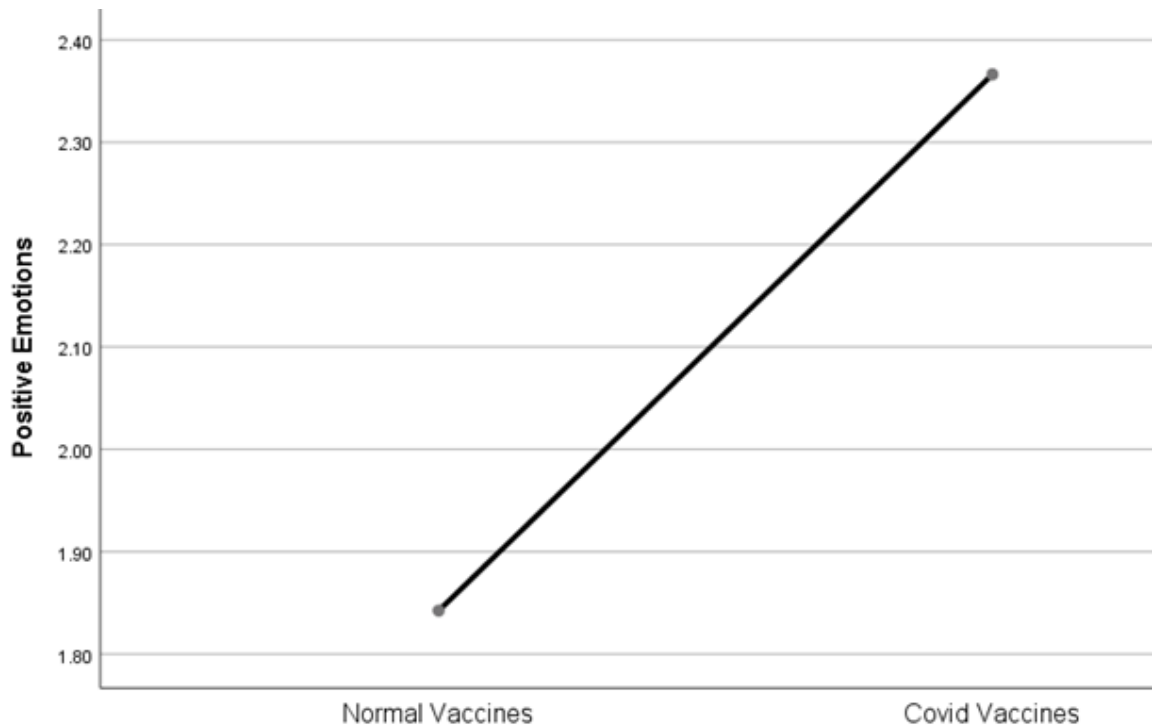


Fig. 1. (A) Comparisons of positive affect between tweets

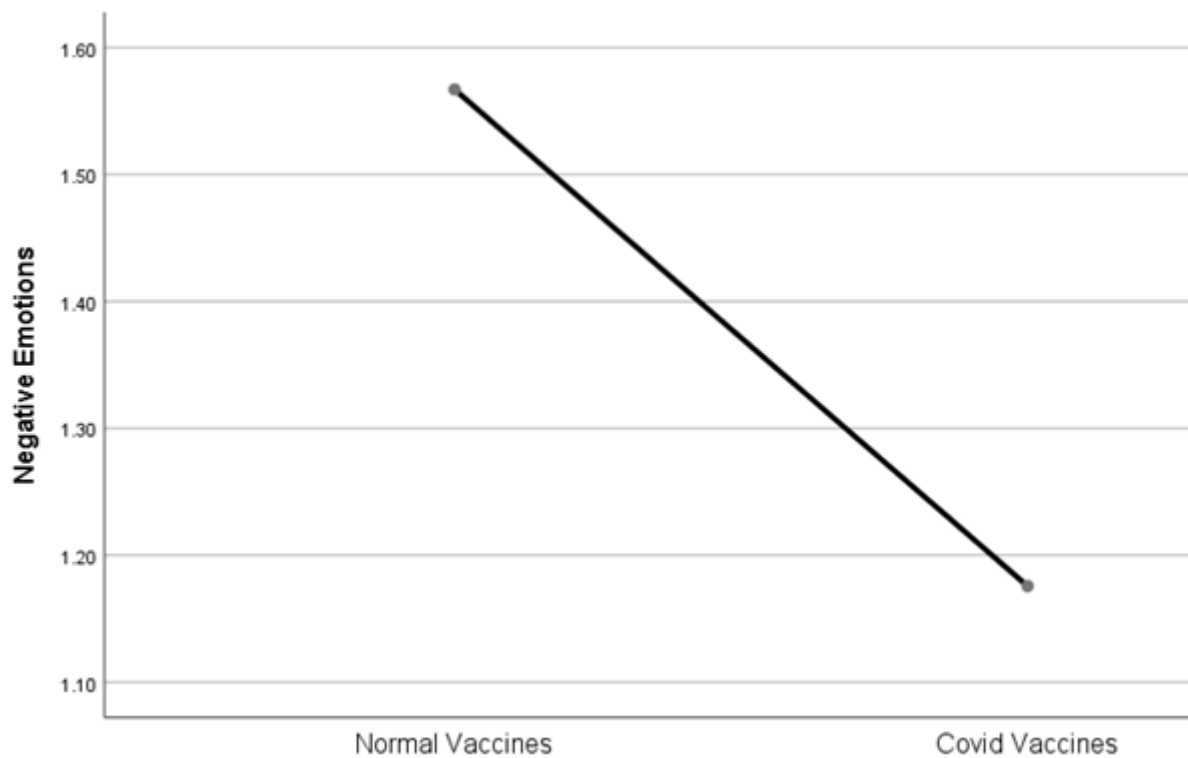


Fig. 1. (B) Comparisons of negative affect between tweets

The distinction in public sentiment between COVID-19 and traditional vaccines, particularly in terms of achievement, represents a pivotal aspect of contemporary health communication. Our analysis revealed a pronounced sense of achievement surrounding COVID-19 vaccines, reflecting a broader social and psychological narrative. COVID-19 vaccine-related tweets exhibited an achievement sentiment score of 0.70, compared to 0.50 for traditional vaccines ($p < 0.01$). This difference highlights the unique context surrounding COVID-19 vaccines, where their rapid development, approval, and deployment were perceived as a monumental success in the face of a global crisis (Pennycook et al., 2020; Lazer et al., 2021). This resonates with societal needs for hope and progress amidst adversity.

This public sentiment aligns with the concept of collective efficacy, where the successful development of vaccines is seen as a direct result of global scientific collaboration and innovation, reinforcing a collective belief in the ability to overcome the pandemic (Bandura, 1997). The heightened positive sentiment and sense of achievement related to COVID-19 vaccines are further contextualized by the psychological impact of prolonged isolation and disruption caused by the pandemic. Studies have shown that the longing for a return to normalcy has significantly influenced public attitudes towards vaccination, with COVID-19 vaccines symbolizing a tangible path out of the pandemic (Brooks et al., 2020). This contrasts with the sentiment towards traditional vaccines, where the absence of an immediate crisis context may diminish the sense of urgency and collective achievement.

Social media platforms, particularly Twitter, have played an unprecedented role in shaping the discourse around COVID-19 vaccines. The amplification of positive milestones in vaccine development and distribution through these platforms has contributed to an enhanced sense of achievement among the public (Chou et al., 2021). This is juxtaposed against the backdrop of traditional vaccine discussions, which may not receive the same level of positive reinforcement or visibility on social media, contributing to variances in public sentiment.

Drawing on the Theory of Planned Behavior (Ajzen, 1991), the positive affect and achievement associated with COVID-19 vaccines can significantly influence intentions and attitudes towards vaccination. The visibility of vaccine progress and success stories, particularly on social media, serves as a powerful motivator, potentially enhancing vaccine uptake by reinforcing positive attitudes and normative beliefs about vaccination efficacy and societal benefit (Myers & Goodwin, 2011).

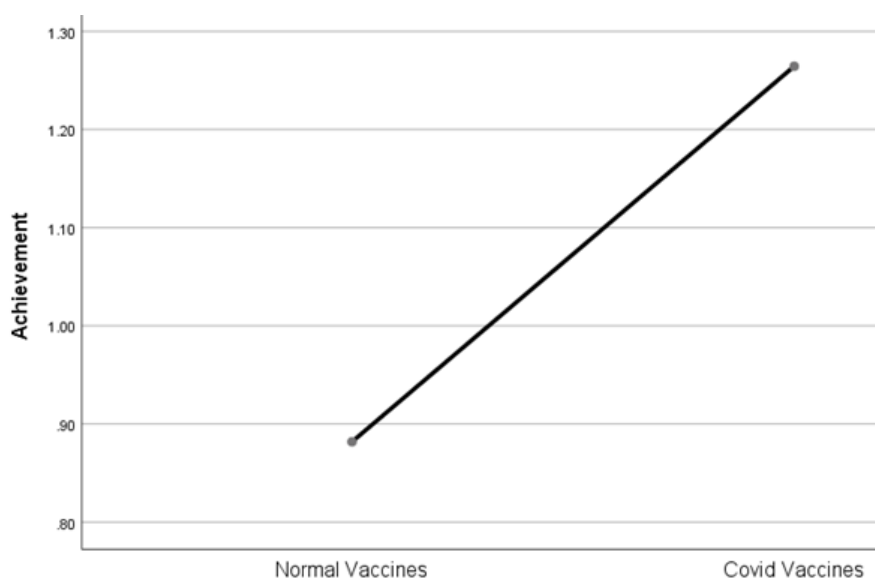


Fig. 2. Comparisons of achievement

The global crisis induced by the COVID-19 pandemic has profoundly altered the landscape of public health risk perceptions, particularly regarding vaccination. Our comprehensive analysis reveals distinct differences in risk perceptions between COVID-19 vaccines and traditional vaccines, shedding light on the multifaceted factors influencing these perceptions.

The advent of COVID-19 vaccines has been met with a complex mixture of optimism and apprehension, reflecting a significant shift in risk perception dynamics. This shift is underscored by a heightened sense of urgency and a collective desire for a resolution to the pandemic, factors that have substantially influenced public attitudes towards the perceived risks of COVID-19 vaccines (Cori et al., 2020; Largent et al., 2021). The immediacy of the threat posed by the virus, coupled with the extensive media coverage and public discourse surrounding vaccine development, has created a unique context for evaluating risks and benefits.

Recent studies have illuminated the contrast in risk perceptions, with data indicating a general tendency among the public to perceive COVID-19 vaccines as less risky compared to traditional vaccines. This perception is partly attributed to the extensive scientific and media focus on the safety and efficacy of COVID-19 vaccines, which has played a pivotal role in shaping public attitudes (Wood & Schulman, 2021). Additionally, the immediacy of the COVID-19 threat has led to a recalibration of risk-benefit analyses, with many individuals viewing the potential risks of vaccination as outweighed by the benefits of protection against the virus (Betsch et al., 2020).

From a theoretical perspective, the Health Belief Model provides a valuable framework for understanding these observed disparities in risk perceptions. According to this model, individuals' decisions about health behaviors, such as vaccination, are influenced by their perceptions of the severity of a health threat, the benefits of taking action, and the barriers to taking such action (Rosenstock et al., 1988). The unprecedented nature of the COVID-19 pandemic has amplified the perceived severity of the threat, thereby altering the calculus of risk perception associated with COVID-19 vaccines relative to traditional vaccines. In the face of a novel and potentially deadly virus, the perceived benefits of vaccination may outweigh the perceived risks for many individuals.

Moreover, the role of social and psychological factors in shaping risk perceptions cannot be overstated. The collective experience of the pandemic, characterized by widespread anxiety and uncertainty, has engendered a communal sense of vulnerability and a shared eagerness for solutions. This social context has contributed to a more favorable perception of the risks associated with COVID-19 vaccines, as they are seen as instrumental in facilitating a return to normalcy (Dryhurst et al., 2020). The desire to protect oneself and contribute to the collective well-being may further motivate individuals to accept the perceived risks of vaccination.

In conclusion, the COVID-19 pandemic has reshaped the landscape of risk perception, particularly in the context of vaccination. The perceived lower risk associated with COVID-19 vaccines compared to traditional vaccines reflects a complex interplay of factors, including the urgency of the pandemic, the extensive media coverage of vaccine development, and the social and psychological impact of the crisis. Understanding these dynamics is crucial for developing effective public health communication strategies that address public concerns and promote informed decision-making about vaccination.

The evaluation of death perceptions associated with traditional and COVID-19 vaccines reveals a complex interplay of psychological, demographic, and socio-political factors that shape public attitudes towards vaccine-related risks. Integrating the latest empirical research and theoretical insights, we delve deeper into the dynamics at play.

The COVID-19 pandemic has heightened public sensitivity to health risks, altering perceptions of mortality associated with various diseases and their respective vaccines. Research by Bavel et al. (2020) underscores how collective experiences of threat can shift societal values and norms, affecting risk assessment processes. In this context, the perceived lower mortality risk from COVID-19 vaccines reflects a broader psychological response to the pandemic, with the public gravitating towards solutions that promise a return to normalcy. The desire to overcome the crisis and resume pre-pandemic life may lead individuals to downplay the potential risks associated with COVID-19 vaccines.

Demographic factors also play a significant role in shaping death perceptions. Recent analyses reveal that younger populations, who are predominantly active on platforms like Twitter, exhibit lower mortality rates from COVID-19 (Sousa et al., 2020). This demographic profile significantly influences the collective perception of COVID-19's risk, contrasting with the more generalized threat posed by diseases targeted by traditional vaccines. The differential impact of COVID-19 across age groups thus plays a crucial role in shaping perceptions of vaccine-related death risks. Younger individuals, who may

perceive themselves as less vulnerable to the severe effects of COVID-19, may be less concerned about the potential risks of vaccination.

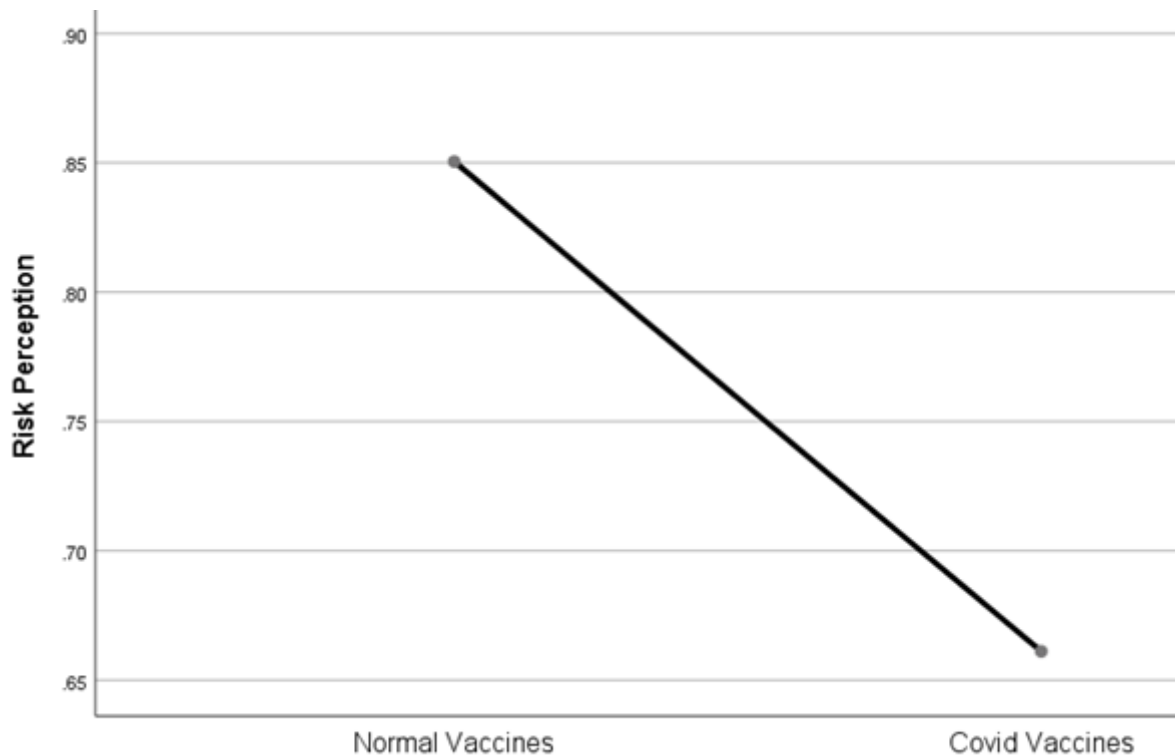


Fig. 3. Comparisons of Risk perceptions

Furthermore, the disparity in mortality rates between COVID-19 and diseases prevented by traditional vaccines further informs public risk perceptions. For example, while diphtheria's mortality rate in certain regions stands at 3.5% (Arguni et al., 2021), COVID-19's global mortality rate is estimated at around 2% (WHO, 2021). Such comparisons contribute to the narrative that COVID-19, though severe, presents a relatively lower risk of death than some other diseases, influencing the public's perception of the vaccines. This may lead to a perception that the benefits of COVID-19 vaccination outweigh the risks, while the risks associated with traditional vaccines may be perceived as more significant due to the higher mortality rates of the diseases they prevent.

Finally, the polarization of vaccine discourse on social media, often exacerbated by political figures and influencers, significantly impacts public perceptions of disease severity and vaccine safety (Walter et al., 2020). This phenomenon, where authoritative voices can sway public opinion, may dilute perceptions of risk associated with COVID-19, contributing to a more favorable view of the COVID-19 vaccine's risk profile. The constant exposure to conflicting information and opinions can create confusion and uncertainty, potentially influencing individuals' risk assessments and decision-making regarding vaccination.

In conclusion, the perception of death risk associated with vaccines is a multifaceted issue, influenced by psychological responses to the pandemic, demographic trends, comparative mortality rates, and the polarizing effects of social media. This complex scenario highlights the need for nuanced public health messaging that accurately conveys the risks and benefits of vaccination against both COVID-19 and traditional vaccine-preventable diseases. By addressing these diverse factors and tailoring communication strategies to specific audiences, public health authorities can promote informed decision-making and enhance vaccine acceptance.

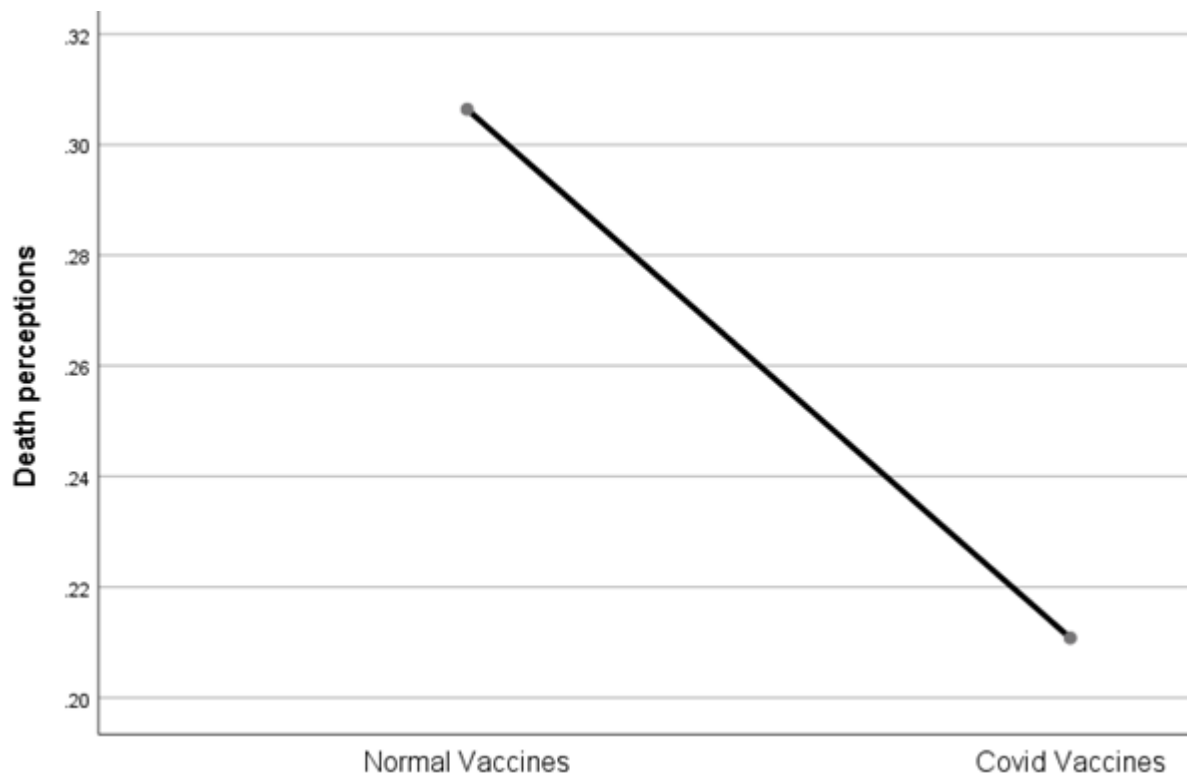


Fig. 4. Comparisons of death perceptions

This analysis explores the complex factors shaping public perceptions of COVID-19 severity and vaccine efficacy on Twitter, moving beyond simple epidemiological data to consider the intricate web of influences at play.

Firstly, Twitter's predominantly younger user base, who statistically face lower risks from COVID-19 (Smith & Graham, 2020), influences the platform's collective perception of the pandemic's severity. This demographic skew may lead to a less pronounced sense of urgency. This highlights the need for tailored public health messages that resonate with specific audience segments, such as emphasizing the potential long-term effects of COVID-19 or the importance of protecting vulnerable populations when communicating with younger audiences.

Secondly, the inclusion of diseases with varying mortality rates in the discourse allows for comparative risk assessment. Notably, diseases like diphtheria, with higher mortality rates in certain contexts (WHO, 2021), can diminish the perceived severity of COVID-19. This underscores the need for clear communication regarding the risks associated with different pathogens, emphasizing that while COVID-19 may have a lower mortality rate than some diseases, it still poses a significant threat.

Thirdly, the compressed timeline of the COVID-19 pandemic compared to longer historical health crises adds another layer of complexity. The rapid development and deployment of vaccines within this shortened timeframe influences perceptions of the pandemic's manageability (Lewnard & Lo, 2020). Public health strategies must acknowledge this temporal aspect, addressing complacency and fostering sustained commitment to vaccination and preventive measures.

Finally, the polarization of vaccine discourse, amplified by ideological divides and influential figures (Van Bavel et al., 2020), poses a significant barrier to a cohesive public health response. This ideological lens can dramatically alter perceptions of vaccine efficacy and safety. Effective communication strategies must address concerns across the political spectrum and build trust in scientific evidence and public health institutions.

In conclusion, understanding the multifaceted dynamics influencing perceptions of COVID-19 on Twitter necessitates a nuanced, multidisciplinary approach to public health communication. By

integrating insights from demographic studies, comparative epidemiology, temporal analysis, and sociopolitical research, public health authorities can better navigate social media discourse. Effective communication strategies must be adaptive, evidence-based, and sensitive to the diverse factors shaping public perceptions in the digital age.

CONCLUSIONS

This study investigated the complex landscape of public health communication during the COVID-19 pandemic, with a specific focus on the divergent public sentiments towards COVID-19 vaccines compared to traditional vaccines. Our analysis of Twitter discourse revealed a statistically significant contrast in sentiment: a more pronounced positive sentiment and a reduced negative sentiment towards COVID-19 vaccines. This disparity can be attributed to a confluence of interconnected factors, operating at the individual, social, and contextual levels. We interpret these findings through the lens of established theoretical frameworks and discuss their implications for public health communication.

The demographic composition of Twitter users, which skews towards younger individuals (Auxier & Anderson, 2021), likely contributed to the observed sentiment differences. Younger demographics, statistically less likely to experience severe COVID-19 outcomes, may exhibit an attenuated perception of the pandemic's overall threat (Smith & Graham, 2020), aligning with the well-documented optimism bias (Bracha & Brown, 2012; Weinstein, 1980). This bias, where individuals underestimate their susceptibility to negative events, can lead to a diminished perception of risk associated with COVID-19 and a correspondingly more positive view of vaccines. This highlights the crucial need for tailored public health communication strategies that address the specific risk perceptions and informational needs of different demographic groups, particularly younger populations.

The unique context of the COVID-19 pandemic, characterized by widespread lockdowns and social distancing measures ("quarantine"), significantly heightened public anticipation for a vaccine. The COVID-19 vaccine was widely framed as a symbol of hope and a pathway to a return to pre-pandemic normalcy (Brooks et al., 2020; Rubin et al., 2021). This intensified expectation likely mitigated perceived risks associated with the vaccine, illustrating the powerful influence of situational context on risk perception and health behavior. This aligns with Anxiety-Uncertainty Management Theory (Gudykunst, 2005), which suggests that positive sentiments towards the vaccine may have served as a coping mechanism to manage pandemic-induced anxiety and uncertainty. Furthermore, the relatively compressed timeframe of the COVID-19 pandemic, compared to the longer historical timelines of diseases addressed by traditional vaccines, might contribute to a perception of its transience (Lewnard & Lo, 2020). This could lead to an underestimation of the pandemic's long-term severity and impact. Public health messaging should therefore emphasize not only the immediate benefits of vaccination but also the potential long-term consequences of COVID-19 infection, including "long COVID" (Sudre et al., 2021).

Selective Exposure Theory (Stroud, 2014) provides a framework for understanding how individuals actively select information that confirms their pre-existing beliefs, contributing to the formation of echo chambers and filter bubbles on social media (Pariser, 2011). This selective exposure, combined with the optimism bias, can further diminish risk perception, particularly among younger demographics who may be more likely to consume information from online sources that downplay the severity of COVID-19. This underscores the imperative for diversifying communication channels and tailoring messaging to reach individuals with varying pre-existing beliefs and levels of risk perception. Addressing misinformation and promoting media literacy are crucial components of this effort.

The pervasive polarization of online discourse, particularly along political and ideological lines, significantly impacts perceptions of both disease severity and vaccine efficacy (Walter et al., 2020; Allcott & Gentzkow, 2017). This polarization can distort factual information and contribute to divergent sentiments, hindering effective public health communication. The Theory of Planned Behavior (Ajzen, 1991) further elucidates how positive sentiments, social norms, and perceived behavioral control (influenced by factors like misinformation and polarization) collectively influence vaccination attitudes

and intentions. This emphasizes the importance of addressing misinformation at its source, fostering bipartisan support for public health initiatives, and promoting trust in scientific and medical institutions.

In conclusion, our findings illuminate the complex interplay of demographic trends, psychological biases (optimism bias, availability heuristic), contextual factors (pandemic, quarantine), and social media dynamics (selective exposure, polarization, misinformation) in shaping public sentiment toward COVID-19 vaccines compared to traditional vaccines. The pronounced positive sentiment and more nuanced risk perceptions observed for COVID-19 vaccines underscore the multifaceted nature of vaccine perceptions during a global health crisis. These insights provide a foundational understanding of the factors influencing online vaccine discourse and emphasize the critical need for nuanced, targeted, and evidence-based public health communication strategies that address the specific concerns, beliefs, and informational needs of diverse populations. Future research should explore the long-term effects of these factors on vaccine uptake and the evolution of public sentiment over time.

Contributions to literature

This study makes several significant contributions to the existing body of literature on vaccine perceptions, digital health communication, and the application of social media analytics to public health. By integrating a large-scale Twitter dataset with established and emerging theoretical frameworks, and by employing a comparative analysis of COVID-19 and traditional vaccines, this research extends the applicability of these theories within the unique context of a global health crisis and offers novel, actionable insights.

Firstly, our findings provide empirical support for, and extend the application of, Selective Exposure Theory (Stroud, 2014) within the context of a rapidly evolving public health crisis. We demonstrate how digital platforms, specifically Twitter, can amplify selective exposure to vaccine-related information, contributing to the formation and reinforcement of echo chambers and filter bubbles (Pariser, 2011). This is a crucial extension of the theory, as it moves beyond traditional media consumption to examine the dynamics of selective exposure in the age of algorithmic curation and social media polarization (Garrett, 2009; Zuiderveen Borgesius et al., 2016). Our findings highlight the importance of understanding the interplay between digital information consumption behaviors, social media algorithms, and the reinforcement of pre-existing beliefs in shaping public health attitudes.

Secondly, this research advances our understanding of the Optimism Bias (Sharot, 2011) and its specific influence on perceptions of COVID-19 severity and vaccine efficacy, particularly among younger demographics who constitute a significant proportion of Twitter users. This provides critical insights into the psychological mechanisms underlying vaccine hesitancy and acceptance, demonstrating that optimism bias is not a static trait, but rather a dynamic construct that is influenced by contextual factors, such as the perceived immediacy and severity of a health threat (Helweg-Larsen & Shepperd, 2001; Weinstein, 1980). This finding underscores the need for targeted communication strategies that directly address optimism bias and tailor risk communication to specific demographic groups.

Thirdly, by applying Anxiety-Uncertainty Management Theory (Gudykunst, 2005) to the pandemic setting, our analysis reveals how positive sentiments towards COVID-19 vaccines can function as a coping mechanism for managing pandemic-related anxieties and uncertainties. This extends the theory's application beyond its traditional focus on intercultural communication to encompass health communication during large-scale public health emergencies (Stephan et al., 1999). This highlights the potential for leveraging positive emotions and framing vaccination as a means of regaining control and reducing uncertainty in future public health crises.

Furthermore, this research makes a novel contribution to the understanding of demographic factors in shaping vaccine sentiment by directly linking Twitter users' age distribution (as inferred from platform demographics) to observed patterns of sentiment expression. By correlating demographic trends with sentiment analysis results, we provide empirical evidence for the influence of age on perceptions of risk and efficacy, contributing to a more comprehensive and nuanced understanding of

health behavior theories in the context of social media and digital communication (Smith & Graham, 2020; Majmundar et al., 2021).

Finally, our exploration of the impact of political and ideological polarization on vaccine perceptions offers critical contributions to the fields of Health Communication and Political Psychology. We elucidate the complex dynamics of social media polarization, demonstrating how partisan divides and the spread of misinformation can significantly influence attitudes towards both COVID-19 and traditional vaccines (Walter et al., 2020; Allcott & Gentzkow, 2017). This underscores the critical importance of developing nuanced, evidence-based communication strategies that are capable of navigating these ideological divides, addressing specific anxieties and misinformation prevalent within different groups, and fostering trust in scientific evidence and public health institutions (Van Bavel et al., 2020; Druckman, 2015). Importantly, our comparative approach highlights that the dynamics of polarization may differ between novel and established vaccines, requiring tailored communication strategies.

This study also offers a methodological contribution by demonstrating the value of integrating large-scale social media data with established theoretical frameworks to understand complex public health phenomena. The use of sentiment analysis, specifically LIWC, combined with statistical analysis, provides a robust and replicable approach for investigating the nuances of online vaccine discourse.

In conclusion, this study provides significant and multifaceted contributions to the literature by validating, extending, and integrating existing theories, while also offering novel insights into the role of demographic, socio-political, and contextual factors in shaping public sentiment towards vaccines during a global health crisis. This research paves the way for future investigations into the long-term impacts of the pandemic on vaccine perceptions and informs the development of more effective and targeted health communication strategies in the digital era, both for current and future public health challenges.

Limitations and future research directions

While this study provides valuable insights into the factors shaping public perceptions of COVID-19 and traditional vaccines on Twitter, it is essential to acknowledge its limitations and delineate avenues for future research. These limitations, and the corresponding research directions, are outlined below.

Firstly, the reliance on Twitter data as the sole source of information presents a limitation regarding the generalizability of the findings. Twitter's user base is not demographically representative of the general population, exhibiting a skew towards younger individuals and those with higher levels of education (Auxier & Anderson, 2021; Mellado et al., 2021). Consequently, caution must be exercised when extrapolating these findings to other populations or communication platforms. Future research should incorporate data from a wider range of social media platforms (e.g., Facebook, Instagram, YouTube, TikTok) and, ideally, integrate survey data or other forms of data collection to achieve a more comprehensive and representative understanding of public sentiment. Furthermore, exploring cross-cultural differences in vaccine sentiment using multilingual datasets would be a valuable addition.

Secondly, while sentiment analysis tools, including LIWC, offer considerable advantages for analyzing large-scale textual data, they are not without limitations. These tools may not fully capture the subtle nuances of human language, such as sarcasm, irony, humor, and complex sentence structures, potentially leading to misinterpretations of sentiment (Pang & Lee, 2008; Hutto & Gilbert, 2014). Future research should explore the integration of more advanced natural language processing (NLP) techniques, including deep learning models and contextualized word embeddings, to improve the accuracy and robustness of sentiment detection, particularly in the context of complex and evolving online discourse (Yadav & Vishwakarma, 2020; Zhang, Ghosh, Dekhil, Hsu & Liu, 2011). Additionally, incorporating qualitative analysis of a subset of tweets could provide a richer understanding of the context and meaning behind expressed sentiments.

Thirdly, while this study touched upon the influence of echo chambers and filter bubbles, a more in-depth analysis of these phenomena is warranted. Future research should delve deeper into the structural characteristics of online social networks, examining the role of network topology, information

diffusion patterns, and algorithmic amplification in shaping vaccine perceptions and contributing to polarization (Cinelli et al., 2021; Eady et al., 2023). This could involve employing network analysis techniques to map the flow of information and identify influential nodes within the network. Agent-based modeling could also be used to simulate the spread of misinformation and the impact of different intervention strategies.

Future research should prioritize longitudinal studies to track the temporal dynamics of vaccine perceptions, particularly in response to evolving scientific evidence, public health campaigns, and real-world events (e.g., new variants, changes in vaccine recommendations). This could provide valuable insights into the persistence or malleability of vaccine sentiments and the long-term effectiveness of public health interventions (Ruths & Pfeffer, 2014; Kim & Shah, 2021). Furthermore, while this study identifies correlations between various factors and vaccine sentiment, establishing causal relationships requires further investigation. Experimental and quasi-experimental designs, such as A/B testing of different communication strategies on social media, could provide stronger evidence for causality (Broniatowski et al., 2018; Oeldorf-Hirsch & Sundar, 2016).

Moreover, future research should expand the scope of investigated factors to include a more comprehensive examination of demographic, psychographic, and socio-economic variables that may influence vaccine perceptions (Larson et al., 2014; Hornsey et al., 2018). This could involve incorporating data on political affiliation, religious beliefs, health literacy, trust in institutions, and personal experiences with vaccination. Qualitative research methods, such as interviews and focus groups, could provide richer insights into the underlying motivations and beliefs driving vaccine hesitancy or acceptance.

Finally, rigorous experimental research is needed to evaluate the effectiveness of various communication strategies in promoting vaccine confidence and uptake within social media environments. This may involve testing the impact of different message framing techniques (e.g., gain-framed vs. loss-framed messages), source credibility manipulations (e.g., expert vs. peer endorsements), and the use of emotional appeals (e.g., fear appeals, empathy appeals) on vaccine acceptance (Broniatowski et al., 2018; Tormala & Petty, 2007).

By systematically addressing these limitations and pursuing these suggested research directions, the field can advance its understanding of the complex interplay of factors shaping vaccine perceptions in the digital age and contribute to the development of more impactful and evidence-based public health strategies.

Research ethics statement

This article is the author's own original work, which has not been previously published elsewhere.

Author contribution statement

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