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The Covid-19 Information Void: How Pro-Vaccination Voices Lost the Narrative in South Africa

Davide Morselli [1], Maite Beramendi [1,2,3], Andrés Martinez Torres [1], Nnaemeka Ohamadike [4], Melody Sepahpour Fard [5], and Maria Schuld [6]

[1] Institute of Social Science, University of Lausanne, Switzerland
[2] Institute of Psychology, University of Buenos Aires, Argentina
[3] National Scientific and Technical Research Council (CONICET), Argentina
[4] Centre for Applied Data Science, University of Johannesburg, South Africa
[5] Center for Research Training in Foundations of Data Science, University of Limerick, Ireland
[6] Department of Psychology, University of Johannesburg, South Africa

Correspondence: Davide Morselli (davide.morselli@unil.ch)

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Abstract

The erosion of public trust in health information and government communication, particularly during crises like the Covid-19 pandemic, highlights a critical challenge in how health policies are transmitted and received. This study examines the dramatic shift in public sentiment toward Covid-19 vaccination in South Africa during 2021, a period that saw a decline from initial high acceptance to significant hesitancy. We argue that a process of social media selection allowed extreme views to proliferate as official sources retreated. Our findings suggest that sustained or increased mainstream media engagement, particularly from official sources like government and health authorities, could have mitigated the dominance of anti-vaccine narratives and have crucial implications for government communication and public health policies in the digital age. We collected and classified 482,450 original tweets about vaccination. We show that, by the end of 2021, Twitter activity was characterized by a progressive surge in anti-vaccination tweets and a decline in pro-vaccination and factual information, particularly from mainstream media. This shift mirrors the decrease in actual vaccination rates. Employing agent-based modeling, we simulated counterfactual scenarios to assess the impact of media presence on vaccine discourse. The results indicate that sustained or increased media engagement could have mitigated the dominance of anti-vaccine narratives. Conversely, a simulated media downturn led to a steeper decline in pro-vaccination content. The findings suggest that mainstream news media play a crucial role in shaping public perceptions of and support for health policies and that their disengagement creates an informational void exploited by misinformation.

Keywords
anti-vaccine narratives; government communication; health communication; news media; social media; vaccine hesitancy; Twitter; X

1. Introduction

The 2021 Covid-19 vaccination campaign in South Africa presents a compelling case study for social and communication scientists. Initially, public sentiment indicated strong support for vaccination, with polls suggesting that up to 80% of the population was in favor (Cooper et al., 2021). However, this promising forecast took an unexpected turn. A significant decline in vaccination support occurred throughout the year, with only half of the population supporting vaccination by mid-2021 and a mere third having received the vaccine by the end of the year. This dramatic shift from widespread acceptance to hesitancy is the central puzzle of this study, and understanding its dynamics offers insights for government and public health communication strategies in the digital age. This case study provides insights into how public health organizations, government agencies, and news media outlets could leverage online platforms for timely and transparent communication to counter misinformation and promote media literacy.

To understand the dynamics of this sharp change in opinion, we examine social media platforms as a critical arena for public discourse and debate surrounding vaccination. Although public opinion and opinions on social media do not necessarily overlap (Murphy et al., 2014; Reveilhac et al., 2022), social media platforms serve as a "theatre of debates," offering a unique lens through which to observe the evolution of opinions. In doing so, the pivotal role of news media in shaping these social media debates is investigated in this research. Specifically, how news media outlets engaged with, or failed to engage with, the evolving opinions of citizens regarding vaccination is examined. By analyzing the interaction between news media and citizen opinions on social media, the aim of this research is to shed light on the factors that contributed to the dramatic shift in vaccination support in South Africa during 2021 and to understand the broader implications for public health communication and policy implementation in the digital age.

In this study, we articulate a descriptive analysis of the stance on South African Covid-19 vaccination on social media. We then incorporate counterfactual scenarios by means of agent-based modeling (ABM) to investigate the role that news media had or could have had in opposing vaccination hesitancy.

1.1. The South African Puzzle

During the Covid-19 pandemic, the primary global objective was to achieve herd immunity through extensive vaccination campaigns. Despite this unified goal, national, continental, and global surveys revealed that vaccine hesitancy and refusal posed significant obstacles to reaching this collective milestone (Cooper et al., 2021; Sallam et al., 2022). To achieve the goal of herd immunity, South Africa provided Covid-19 vaccinations to its citizens at no cost, becoming one of the first African countries to receive Covid-19 vaccines (Dzinamarira et al., 2022). Throughout 2020, vaccination acceptance rates in South Africa were very high, ranging from 68% to 82% (Cooper et al., 2021).

However, vaccination efforts faced a setback owing to the AstraZeneca/Oxford Covid-19 vaccine's low efficacy against the prevalent 501Y.V2 variant. The focus of the country then shifted to the Johnson & Johnson Covid-19 vaccine, and 80,000 doses were distributed starting on February 17, 2021 (Dzinamarira et al., 2022). This setback resulted in a progressive erosion in public trust in the vaccination program.

During the roll-out in 2021, the willingness to vaccinate within this demographic gradually decreased, falling within the 52% to 65% range (Cooper et al., 2021; Lazarus et al., 2021; Sallam et al., 2022; Wiysonge et al., 2022). According to the Ipsos survey (Cooper et al., 2021), South Africa, along with France, was among the countries with the greatest increase in vaccine hesitancy. While surveys captured this declining trend, the actual percentage of the population that became fully vaccinated was even lower than anticipated: South Africa should have vaccinated 67.25% of the population to reach herd immunity; nevertheless, only 35.47% were fully vaccinated by the end of 2021 (World Health Organization, n.d.).

Various studies have explored the reasons for Covid-19 vaccine hesitancy (Burger et al., 2021; Cooper et al., 2021; George et al., 2024; Kollamparambil et al., 2021; Lazarus et al., 2021; Sallam et al., 2022; Wand et al., 2023; Wiysonge et al., 2022). According to these studies, vaccine hesitancy has been associated with adverse safety perceptions, concerns regarding potential side effects, a lack of trust in the government and the scientific processes underpinning vaccine development, skepticism concerning vaccine efficacy, the perception of insufficient personal risk from Covid-19, misinformation and, to a lesser extent, the endorsement of conspiracy theories.

For these reasons, effective communication strategies are essential for governments to address the root causes of vaccine hesitancy (Page & Hansson, 2024) as well as to monitor and respond to emerging concerns in real time. In this context, analyzing social media platforms such as Twitter (renamed X in 2023) can offer valuable insights into public sentiment and the spatial dynamics of health-related discourse. As Ogbuokiri et al. (2022, 2025) reported, clustered social media activity may serve as an early indicator of evolving attitudes toward community-based responses to infectious diseases.

2. Literature Review

2.1. News Media and Health Policies

In the current information ecosystem, traditional news media and social media platforms constitute key arenas where people access information about local, national, and global events, as well as public guidance and policies (Love et al., 2023). Within this media landscape, governments seeking to inform and persuade citizens must navigate a highly interconnected and competitive space where news organizations, digital platforms, and user-generated content continually shape public discourse. During health crises such as the Covid-19 pandemic, this task has become even more critical: Governments are expected not only to coordinate policy and manage logistics but also to communicate in ways that are timely, transparent, and responsive to public concerns (Górska et al., 2022; Page & Hansson, 2024).

To achieve this goal, governments draw on both mainstream media and digital platforms to reach diverse segments of the population. On the one hand, traditional news outlets continue to structure the flow of information and play a critical role in conferring legitimacy, authority, and coherence to official messages

(Flaxman et al., 2016). On the other hand, governments increasingly rely on social media platforms for real-time, direct communication, enabling them to broadcast instructions, express solidarity, and respond to public concerns without the intermediation of journalists (Leong et al., 2023; Page & Hansson, 2024). These platforms not only support unmediated announcements and policy clarifications but also allow for targeted strategies that reach specific segments of the population. During the Covid-19 pandemic, the social media accounts of health ministries, political leaders, and public agencies became key sources of official information. Government posts often combined instructive content (e.g., how and where to get vaccinated) with emotional appeals aimed at fostering solidarity and trust (Page & Hansson, 2024; Vincent et al., 2023). In the Italian case, for example, Lovari (2020) showed how the Ministry of Health used Facebook to actively counter misinformation by amplifying credible influencers using hashtags, addressing fake news directly, and clarifying measures through data and visuals. Her analysis highlights that, in contexts of extreme uncertainty, strategic, transparent, and proactive communication on social media is fundamental for maintaining public trust.

This hybrid model becomes especially relevant in the context of major crises, such as the Covid-19 pandemic, when the public's demand for timely and trustworthy information intensifies, and during lockdowns, when the need to be connected is high (Wen et al., 2025). In this context, mainstream media functions as a narrative amplifier, helping frame government decisions within broader public discourses. Studies have shown that vaccine reporting in top national outlets increased substantially during the pandemic with a marked trend toward positive framing despite occasional mentions of side effects (Christensen et al., 2022). Outlets such as *The New York Times* focused on vaccine efficacy and public safety, contributing to a discourse of civic responsibility and national effort (Wen et al., 2025). Such coverage reinforced governmental messages, especially among segments of the population that rely on mainstream media for information validation and coherence. In line with this, studies indicate that individuals who consume news through traditional media, such as national or local newspapers, are more likely to express trust in vaccines than are those who rely primarily on social media (Piltch-Loeb et al., 2021).

Importantly, news media remain central even within digital environments. Rather than being displaced by social media, mainstream outlets have extended their reach by adapting to platforms and sharing content across channels such as X, Facebook, and YouTube. For example, a substantial portion of the most-viewed YouTube videos about Covid-19 vaccination were produced by established news organizations (Basch et al., 2020) and news shared on social platforms continues to shape public discourse and guide informational attention (Turcotte et al., 2015; Walker & Matsa, 2021). South Africa is no exception to this trend: Survey data show a sharp increase in news consumption via social media during the pandemic (Conroy-Krutz et al., 2024).

Beyond their function as communication channels, mainstream media have been shown to exert measurable effects on public attitudes and behaviors related to health. A growing body of research highlights how exposure to news content can shape risk perception, encourage preventive actions, and promote prosocial responses to public health messages. For instance, Brannstrom and Lindblad (1994) demonstrated that media coverage focused on health topics can prompt individuals to reconsider their lifestyle choices. Similarly, Wakefield et al. (2010) reported that health campaigns are more effective when the information is perceived as personally relevant. Clear language, visuals, and reliable sources have also been identified as key factors in boosting public engagement with health messaging (Nickl et al., 2024).

In addition to informing, the media can also model and encourage prosocial behavior. Constructive journalism, which emphasizes positive perspectives and solutions to social problems, has been linked to greater empathy and civic engagement (Mast et al., 2019; McIntyre & Gyldensted, 2018). Drawing on Fredrickson's (2001) positive psychology theory, van Venrooij et al. (2022) argued that positive news content can broaden cognitive and emotional repertoires, fostering behavioral change. Supporting evidence spans media formats from television (Mares & Woodard, 2005) and video games (Greitemeyer & Osswald, 2010) to music (Greitemeyer, 2009; Jacob et al., 2010).

People also actively seek information in response to salient health events, which can spark immediate behavioral responses. For example, Angelina Jolie discussed her health, resulting in a temporary spike in online searches related to genetics and breast cancer treatment, which quickly returned to baseline levels (Bhatti & Redelmeier, 2015). Similarly, the media coverage of Kylie Minogue's early breast cancer diagnosis led to a substantial increase in mammogram appointments, exemplifying how media can drive proactive health behaviors when framing health policies in a way that draws public attention (Chapman et al., 2005). Research on the relationship between news media and traffic accidents in Spain (Lucas et al., 2024) also revealed a correlation between increased news coverage of road safety and a reduction in traffic accidents, suggesting that information campaigns through the media can contribute to safer behaviors.

Finally, mainstream news media can contribute to public health policy by shaping the agenda and framing issues. By prioritizing certain health topics, news media help elevate them within public discourse and policy-making processes. Martinson and Hindman's (2005) study of coverage during a breast cancer screening campaign revealed a positive association between intervention efforts and local newspaper content, suggesting the media's role in building a health promotion agenda. In particular, localized news has been shown to be relevant to audiences, providing information about community-specific health resources and initiatives, thereby increasing engagement and potentially driving changes to behavior (Young et al., 2015). By highlighting contextual information and the societal factors contributing to health problems, the media can move the narrative beyond individual responsibility toward the need for collective action and policy interventions.

2.2. Social Media, Disinformation, and News

As we have already emphasized, with the introduction of social media news, consumption patterns have changed and people engage with news via social media. Although this has led people to access more news daily, it also has several downsides, notably the rapid and widespread dissemination of misinformation. This phenomenon became particularly evident during the Covid-19 pandemic, leading the World Health Organization (2020) to describe it as an "infodemic"—a flood of information, both accurate and false—that makes it difficult for people to find trustworthy sources and reliable guidance.

The spread of misinformation on social media was not only massive but also highly consequential, shaping public perceptions, influencing health behaviors, and eroding public trust in governments and scientific institutions (Cáceres et al., 2022; Cinelli et al., 2020). Research has indicated that misinformation constituted 0.2% to 28.8% of social media posts during this period (Gabarron et al., 2021). The rapid dissemination of false or misleading information not only led to public confusion and the erosion of trust in institutions but also hindered an efficient response to the emergency (Gisondi et al., 2022).

The inherent characteristics of social media platforms make them fertile ground for the spread of misinformation (Cinelli et al., 2020; Mahlous, 2024). During the pandemic, the volume of Covid-19-related content on social media was immense, with one tracking program reporting over 40 million mentions in a single week (Gottlieb & Dyer, 2020). This sheer volume of information circulating on these platforms makes it incredibly difficult for users to discern factual and pertinent content from fake news. The ease with which users share content with their networks, often without critically evaluating its source or veracity, results in information spreading globally in a matter of seconds. In addition, the proliferation of information sources, including nonprofessional news actors, makes it difficult for mainstream media outlets to make their brands visible and distinguishable (Kalogeropoulos et al., 2019). This blurring of the lines between credible journalism and unverified claims significantly contributes to the dissemination of misinformation.

Furthermore, algorithms that provide users with content are designed to maximize user engagement and are likely to prioritize sensational or emotionally charged content which often includes misinformation (Kordzadeh & Ghasemaghaei, 2022). By repeatedly presenting certain content to users with specific profiles or search histories, algorithms can create echo chambers where individuals are primarily exposed to information confirming their existing beliefs, regardless of its accuracy. This can lead to a situation where users are "cloister[ed] from reports on legitimate scientific evidence" (Gisondi et al., 2022, p. 4).

In contrast, mainstream media have the potential to debunk misinformation and promote scientific knowledge. By producing high-quality, fact-checked news reports and making them readily accessible across various platforms including social media, news outlets can counter the spread of misinformation. A key aspect of this role is the ability of journalists to verify sources, contrast false narratives, and present accurate information that aligns with journalistic ethics (Roem & Vanisya, 2024). By upholding these standards, fact-checked news reports contribute to a more informed public debate and support health policies, as exemplified by the aforementioned research (e.g., Christensen et al., 2022; Mahlous, 2024; Martinson & Hindman, 2005; Wakefield et al., 2010; Wen et al., 2025).

However, recent decades have witnessed a deterioration of news quality by professional media (Craig, 2010; Salaverría, 2005). The need to maintain competitiveness in a landscape characterized by time pressure and staff shortages, on the one hand, and growing commercialization and economic challenges, on the other hand, have compromised the quality of journalistic standards, leading to increased shallowness, inaccuracy, or even misinformation (Bogart, 2017; Urban & Schweiger, 2014).

In addition, the overwhelming volume of (dis)information circulating on social media, especially during the Covid-19 pandemic, has made it increasingly difficult for voices to be heard as they are often drowned out by the constant stream of messages. This challenge affects not only social groups and marginalized communities striving for visibility but also governmental organizations. Tufekci (2017) characterized this dynamic as a form of cyber warfare in which the battlefield is virtual rather than physical, yet remains strategically significant. Given the crucial role that mainstream media can play in countering misinformation and supporting effective health policies, their strong presence on social media becomes particularly vital during times of crisis.

Therefore, it is essential for public health organizations, government agencies, and news media outlets to actively engage in the online ecosystem, provide accurate information, and counter misinformation. News organizations can play a vital role in enhancing social media users' news and health literacy as people trust

them and rely on them for information (Chen et al., 2020; Migliorini et al., 2023; Sundani & Motloutsi, 2021). This can be achieved through educational content that explains how to identify reliable sources, recognize common misinformation tactics, and critically evaluate information encountered online before sharing it.

In the case of South Africa, the Covid-19 vaccination campaign started to falter just as pro-vaccination messages in the mainstream media began to fade, gradually becoming submerged in a sea of competing narratives, many of which promoted anti-vaccine positions. In this study, we leverage computational methods to investigate the Twitter landscape during the campaign. We attempt to answer the questions of what happened and whether some measures could have been taken to counteract vaccine hesitancy. In this study, we focus exclusively on news media presence, without examining the content and style of communication. We hypothesize that, beyond the quality of information, its sustained presence and visibility also play a key role in the communication of governmental policies. We expect to find a decline in the presence of mainstream outlets that favored anti-vaccination positions. We also expect this to be related to the fading out of pro-vaccination stances. Thus, we apply ABM to investigate alternative scenarios in which the connection between news outlets and pro-vaccination attitudes might have been tighter and in which the media response might have taken alternative paths.

3. Methods

3.1. Data Acquisition

At the beginning of 2021 in South Africa, social media was used by 41.9% of the population, 60% of whom were between 18 and 35 years old (We are social & Hootsuite, 2021). Twitter was the fifth most common form of social media with a penetration rate of 59.2%. We extracted 482,450 unique original tweets from the Twitter API for all of 2021 by the following vaccine-related keywords: vaccine, vaccination, vax, anti-vax, anti-vaccination, anti-vaccine, antivax, vaxed, vaxxed, unvaxed, unvaxxed, and vaccinated. While the precise number of all relevant tweets remains unknown, this sample focuses on tweets with clear, discernible messages. It enables us to approximate the information a user seeking vaccine-related data on Twitter would likely encounter. Therefore, we are confident that this sample is sufficiently large to discern meaningful trends. To ensure that the tweets were related to South Africa, these keywords were paired with geographic taggers (see Annex 1 in the Supplementary File for the detailed procedure). While this procedure might misattribute some tweets, it mitigates bias contained in relying only on tweets with explicit geographical information (Sloan & Morgan, 2015). The tweets were then divided into four phases that described the evolution of the Covid-19 vaccination campaign:

- Phase 1 (n = 113,552) ranged from 01/02/2021 to 20/02/2021. It corresponds with the launch of the vaccination campaign.
- Phase 2 (n = 91,292) spanned from 21/02/2021 to 20/06/2021, capturing the period in which the vaccination campaign targeted primarily front-line health care workers and individuals aged 60 and above. A total of 2,131,210 people were vaccinated during this period (Mahdi et al., 2021).
- Phase 3 (n = 172,503) ranged from 21/06/2021 to 23/11/2021. It captures the period in which the vaccination campaign was extended to the remaining age groups and professional categories (people vaccinated = 14,639,740), although the Delta variant led to renewed lockdown measures (Mahdi et al., 2021).

- Phase 4 (n = 105,103) spanned from 24/11/2021 until 30/12/2021, representing the moment of failure of the campaign. The Omicron variant was discovered and confirmed cases spiked again. The vaccination campaign slowed with only 2,124,344 newly vaccinated individuals (Mahdi et al., 2021).

The news media tweets were classified using a hand-curated list of 356 news outlets and journalists' handles. Then we applied machine learning to classify the stance of the tweets. First, we manually curated a list of all the mainstream news media and journalist handles in the corpus. A total of 10,717 vaccine-related tweets were emitted by news media sources in 2021. We ran in-depth content analysis on a random sample of 150 tweets per phase to estimate the categories present in the corpus (Kerr et al., 2024). Tweets were initially classified as pro-vaccination, anti-vaccination, factual information, or unclear classification. A corpus of 1,500 tweets per phase was assembled (N = 6,000) and each tweet was categorized by three judges. The final classification was based on the agreement of at least two judges. We generated Word2Vec word embedding on the full corpus and trained a support vector machine (SVM) model to assess the stance of the remaining tweets. SVM models classify data by finding an "optimal line" that maximizes the distance between different categories in a multidimensional space. They are particularly effective and robust for classifying high-dimensional, outlier-prone data, such as text. The SVM model achieved an accuracy of 0.76 (precision: 0.78, recall: 0.76, F1 score: 0.76; see Annex 2 in the Supplementary File for details). As validation of the SVM results, 93% of our hand-curated news media tweets were classified as factual, 5.7% as pro-vax, 1% as uncertain, and 0.3% as anti-vax by the machine. This method has been used in other studies, yielding similar results (Wu et al., 2025).

We analyzed the distribution of the five categories (Provaxxer, Antivaxxer, Factual text, Unclear, and News) in each phase to provide an overview of the progression of the opinions over the year and the role of the news media. Because we were interested not only in describing what happened during the campaign but also in exploring what would have happened if circumstances were different, we simulated a series of scenarios using ABM via the ABM package for R (Ma, 2025) to investigate whether increasing or decreasing news media communication could have changed the proliferation of anti-vaccination stances. ABM is a computational method for understanding the behavior of a system as a whole that relies on simulating the interactions of autonomous agents within a specific time window (Axelrod, 1997). In the simulated system, each agent operates under a defined set of rules governing its interactions with other agents, allowing researchers to observe how the system evolves as these rules are applied. The ABM is particularly useful for studying complex adaptive systems where the overall system behavior is difficult to predict from the behavior of its individual components. This allows researchers to explore counterfactual scenarios by modifying agent behaviors and environmental parameters.

In our model, each agent represents a tweet (or a user tweeting once) in each phase. We used the empirical probabilities of switching categories between Phases 3 and 4 to set the rule at which agents would change their stance. To assess the influence of news media, we posited that an agent would change to a pro-vaccination opinion if it came into contact with news tweets. We investigated two sets of scenarios: one with a 25% probability that this agent would change its opinion and one in which the probability was very high, set to 75%. These values were chosen not as exact empirical measures, but as representative of "moderate" and "high" levels of media influence to test the model's sensitivity to a significant change in media presence. While these parameters are arbitrary and there is no study that indicates which would be a suitable threshold, they illustrate how the system could change when varying the influence of media on

opinions. Therefore, we modeled four scenarios exploring media presence on Twitter: the first reflecting the actual distribution of tweets; the second, in which news completely disappears from the Twittersphere; the third, in which news media presence remains constant over time; and the fourth, in which the volume of news tweets increases.

4. Results

4.1. Transition Between Phases

Figure 1 illustrates the distribution of tweets across different categories and the four phases of the campaign. Each bar represents a category classified in each time phase. The lines flowing between phases represent the number of tweets generated by the same users across those phases. The portions of the bars that do not originate from the previous phase indicate tweets from new users who did not engage in the prior phase.

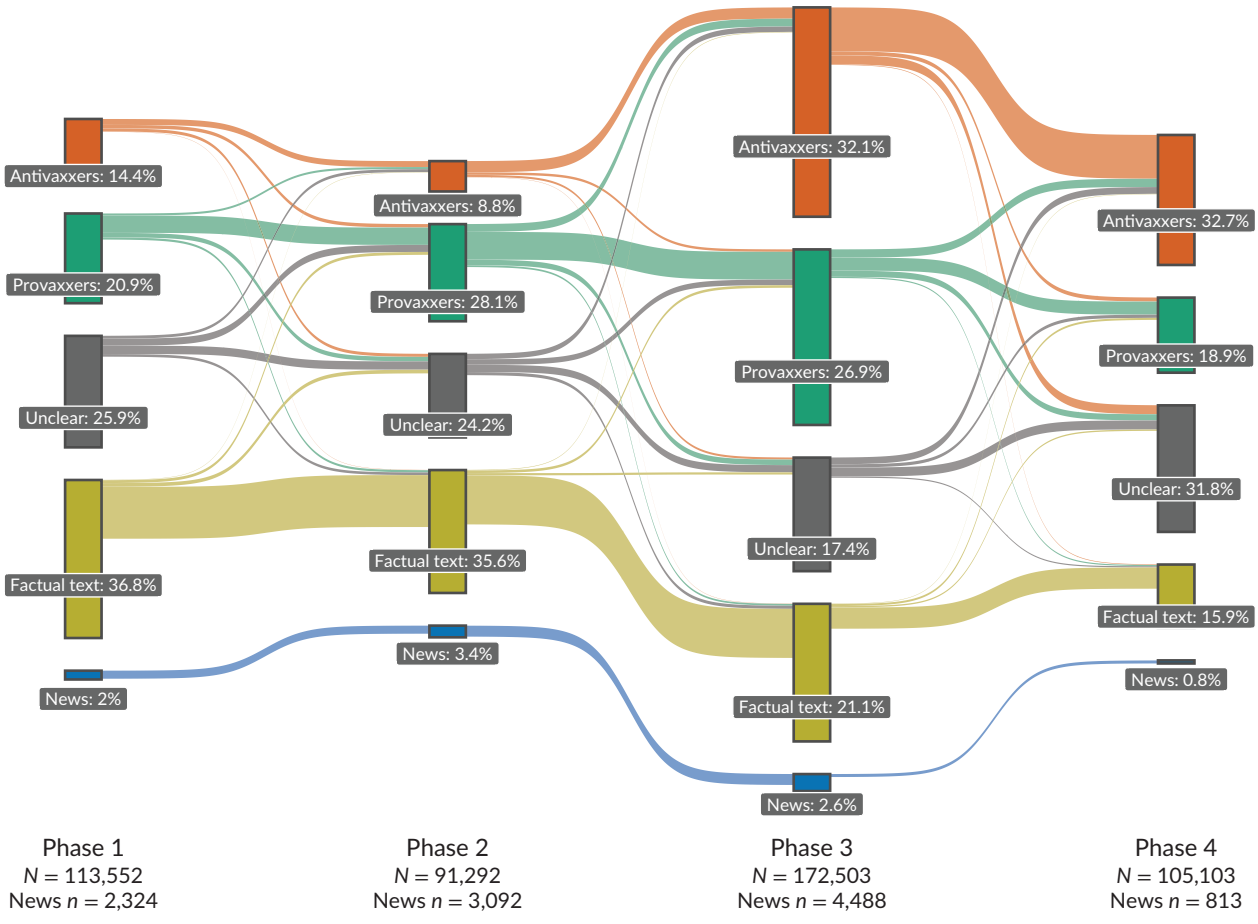

Figure 1. Sankey diagram of transitions between vaccine-related stances across the four phase.

In line with surveys showing support for the vaccine at the beginning of the campaign, the plot shows that anti-vaccination positions were relatively rare during the first two phases. The phases were characterized mainly by the presence of factual texts. The news flow was also consistent, with a steady increase in media tweets from Phase 1 to Phase 3.

The number of anti-vaccination tweets massively increased in the third phase when the government extended the vaccine program to all citizens. However, the number of anti-vaccination and pro-vaccination tweets was fairly similar, with neither position dominating the other. This was not the case in Phase 4. The number of clearly identified pro-vaccination tweets decreased and the number of anti-vaccination tweets became dominant. Notably, the proportion of unclear messages also slightly increased, indicating that distinguishing between overtly anti-vaccination and pro-vaccination discourses was more difficult for the model. Nevertheless, a relatively high portion of antivaxxers from Phase 3 continued to engage in Phase 4, unlike provaxxers.

In line with our hypotheses, the number of mainstream media tweets decreased significantly in Phase 4. Similarly, the factual tweets also declined. This finding indicates that the vaccine discourse on Twitter shifted toward being dominated by opinion-based tweets while factual information became less prevalent. It also suggests a reduced effort from news outlets to disseminate factual information and a corresponding decrease in the sharing of objective data regarding vaccines. Consequently, the online conversation surrounding vaccination became increasingly polarized, with personal opinions and anecdotal evidence taking precedence over verified facts and expert pronouncements.

4.2. Simulation of Media Influence

From the previous analyses, a question arises: What would have occurred had the media not ceased its efforts to promote pro-vaccine information? To address this, we ran a series of agent-based models on the basis of the real-world scenario of changes in the distributions of our five categories between Phases 3 and 4.

We constructed a transition matrix which illustrates the probability distribution of each Phase 3 stance in the subsequent phase. We then simulate the influence of the media by assigning a 25% probability of an agent shifting to a pro-vaccine stance upon interaction with a news outlet. The interaction probability, that is, the probability that an agent would interact with a news tweet, was assessed using a random network with a degree of six, mirroring the average user distance in Phase 4 of our data (Morselli & Beramendi, 2025). Lacking further insight into why other users might have changed their stance, agents were instructed to transition between categories in accordance with our transition matrix. In other words, we did not instruct the model to change according to specific rules but rather to reflect the empirical probability distribution. We conducted the simulations across five time points, where time zero represented the empirical distribution at Phase 3, and each subsequent interval mirrored the change observed between Phases 3 and 4. The following time points approximate what would happen over the following year (i.e., four periods). The simulations were repeated 500 times to obtain more accurate estimates.

We modelled four different scenarios. To assess whether media would have prevented the imbalance in the presence of anti-vaccine tweets, we calculated the difference between anti-vaccination and pro-vaccination distributions using the trapezoidal rule. Smaller differences indicate a less dominant distribution of one of the two positions. Table 1 reports the average difference between the distributions of the simulated pro-vaccination and anti-vaccination effects across the 500 replications for all the scenarios and their 95% confidence intervals.

Table 1. Area difference between anti-vaccination and pro-vaccination simulated distributions.

Scenario	News influence probability = 25%				News influence probability = 75%			
			95% Confidence interval				95% Confidence interval	
	Mean	*SD*	Lower bound	Upper bound	Mean	*SD*	Lower bound	Upper bound
1	17,867.54	366.43	17,116.11	18,520.79	13,471.98	341.48	12,895.63	14,190.06
2	21,108.18	363.63	20,443.05	21,886.81	20,474.88	381.00	19,769.35	21,202.88
3	14,849.11	352.58	14,160.56	15,601.50	8,474.93	385.59	7,743.41	9,314.51
4	13,607.97	358.55	12,898.76	14,281.10	5,957.49	263.11	5,469.89	6,456.08

Notes: The area is calculated with the trapezoidal rule for each ABM replica; the reported statistics refer to the mean, standard deviation (*SD*), and confidence interval over 100 replicas for each scenario.

Scenario 1 (Figure 2, S1) is our baseline model. It captures the transition between Phases 3 and 4 and simulates the evolution of the category distribution across time, with news media dropping out at the empirical rate. In other words, this scenario assumes that news tweets declined at the same rate as they did between Phases 3 and 4. Once the initial distribution and the dropout rates were set, the model was allowed to freely evolve following the programmed interaction rules. Because the rate of decrease of the news was set to the real parameters, we would expect that after the first step (Time 1), the ABM would reproduce the real distribution in Phase 4. Consistent with this hypothesis, and validating our model, the results mirror the dropout rate with reasonably good accuracy, predicting that the tweets would be distributed as Antivaxxer = 12,585, Provaxxer = 8,795, Unclear = 6,088, Factual text = 6,850, News = 887, and Dropout = 137,298 (tweets that were generated in Phase 3 but had no corresponding tweets in Phase 4, meaning the users who created them stopped tweeting about vaccines), compared to the real distribution in Phase 4 of Antivaxxer = 15,608, Provaxxer = 5,855, Unclear = 6,714, Factual text = 6,374, News = 795, and Dropout = 137,157. Interestingly, the model could not exactly estimate the decline in pro-vaccination tweets, even after several parameters were changed. By reproducing the decline observed between Phases 3 and 4, our model mirrors a progressive lack of interest in the vaccination debate over time, confirming the validity of the interaction rules we assigned to the model.

In Scenario 2 (Figure 2, S2), we simulate the sudden drop of tweeting activity by mainstream media, shifting from 4,488 tweets to zero. This ABM shows what would have happened, given our interaction rules, if the news media had disappeared completely from Twitter. In this scenario, the decrease in the rate of pro-vaccination tweets is steeper than that in the previous scenario. The area between the anti-vaccination and pro-vaccination distribution lines increased to 21,108, compared with 17,867 in Scenario 1. This shows that, assuming the minimal influence of mainstream media in promoting pro-vaccine opinions, stopping nudges for pro-vaccine information could have created even more space for anti-vaccine tweeting activity.

To corroborate this hypothesis, we investigated what would have happened if the media presence had remained the same as in Phase 3 (Scenario 3, Figure 2, S3) or even had increased its activity (Scenario 4, Figure 2, S4). Although neither scenario completely contrasted the predominance of anti-vaccine positions, the difference between pro- and anti-vaccine opinions was reduced in both scenarios with the difference between the two positions in Scenario 4 declining by one-fourth compared with that in Scenario 1.

To further expand this investigation, Table 1 also reports the simulations with an influence of 75% of the news on pro-vaccine opinions. This set of simulations assumes that users following mainstream media will convert to pro-vaccine opinions three out of four times. Although this is a completely unrealistic scenario, the simulation shows that, in that case, the difference between pro- and anti-vaccination tweets in Scenario 4 would have been reduced by 60% compared with that in Scenario 1, highlighting the potential role of the media in promoting vaccination willingness.

Finally, it could be argued that the decline of the pro-vaccination group might depend on the size difference between the two groups. In that case, the results would be seriously affected by the misclassification errors of the SVM model. To investigate this issue, we ran a sensitivity analysis by setting the size of the two opinion groups to be equal to the empirical size of the anti-vaccination group in Phase 3. The results reported in Table 2 show a similar trend to those in Table 1, confirming that the difference between the two groups is reduced by a constant presence of news tweets, if news have an influence on opinions.

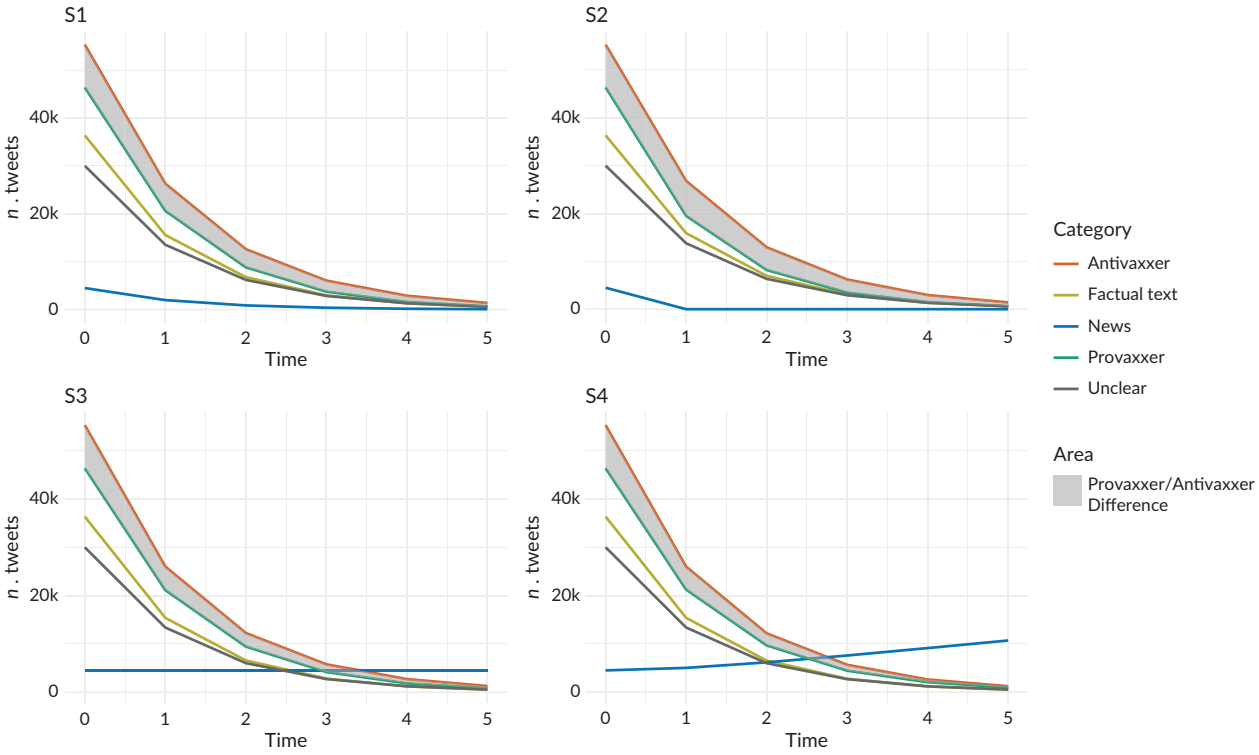

Figure 2. Distribution of stance categories as predicted by the agent-based model with news influence at 25%: S1 is the baseline; S2 is news tweets decrease; S3 is news tweets stabilize; and S4 is news tweets increase. Notes: The y-axis represents the number of tweets, and the x-axis represents the passage of time; time = 0 reports the empirical distributions of tweets in Phase 3 and it is the same in all four scenarios; time >0 displays the change of tweets as simulated by the ABM.

Table 2. Sensitivity analysis: Difference between anti-vaccination and pro-vaccination tweets distribution, setting initial tweets production to be equal.

Scenario	News influence probability = 25%				News influence probability = 75%			
			95% Confidence interval				95% Confidence interval	
	Mean	*SD*	Lower bound	Upper bound	Mean	*SD*	Lower bound	Upper bound
1	8,281.57	361.89	7,677.08	8,866.35	4279.00	305.04	3869.80	4816.10
2	11,396.12	381.26	10,804.55	12,015.53	10871.77	420.42	10218.48	11524.15
3	5,398.11	402.85	4,815.03	6,067.28	2983.59	218.90	2692.45	3374.45
4	4,155.10	359.80	3,575.40	4,771.23	3441.82	369.55	2857.55	4074.45

Notes: Anti-vaccination and pro-vaccination tweets at time = 0–n = 55,299 (number of the anti-vaccination tweets in Phase 3).

5. Discussion

The aim of this study was to investigate the role of social media opinions and mainstream outlets in shaping Covid-19 vaccine hesitancy in South Africa. Our analysis of the tweet distribution across the four defined phases of the vaccination campaign revealed a picture mirroring the passage from vaccination willingness to hesitancy reported in public opinion surveys and vaccination data. The early phases, characterized by strong initial support for vaccination, were dominated by factual information and a relatively low presence of anti-vaccine sentiment. The steady increase in mainstream media tweets during this period indicated a concerted effort to disseminate accurate information and promote vaccine uptake. However, this landscape shifted dramatically as the campaign progressed. The third phase witnessed a surge in anti-vaccine tweets, coinciding with the expansion of vaccine eligibility to the general population. This shift signaled a growing polarization of opinions and a significant challenge to the vaccination program. The final phase, marked by the emergence of the Omicron variant and a slowdown in vaccination rates, further solidified this trend. Anti-vaccine voices became dominant, whereas the presence of pro-vaccine and factual/news tweets dwindled.

A particularly noteworthy finding is the stark decline in news media tweets during between the phase of mass vaccination (Phase 3) and the following, suggesting a potential withdrawal of mainstream media from the vaccine debate on social media. While our analysis does not allow us to determine the exact reasons for this decline, it is plausible that vaccination was no longer considered "newsworthy" and thus faded from online discourse. Studies have shown that exposure to news content from traditional outlets is associated with greater vaccine acceptance (Piltch-Loeb et al., 2021) and that mainstream media played a central role during the pandemic by amplifying pro-vaccine messages, emphasizing efficacy, and promoting a sense of civic duty (Christensen et al., 2022; Wen et al., 2025). The retreat of mainstream media from vaccine coverage may have left an informational void—particularly among users who rely on these outlets for validating facts and making health decisions—subsequently filled by misinformation and anti-vaccine narratives.

This void is particularly significant given that individuals with different vaccination stances rely on distinct sources of information. Pro-vaccine users typically consume news from mainstream media, which supports vaccination efforts, whereas anti-vaccine users often turn to alternative sources that propagate misinformation or conspiracy narratives (Mønsted & Lehmann, 2022). A decline in mainstream news

coverage may reduce the number of governmental messages and pro-vaccine content available, limiting the informational resources that reinforce support for vaccination.

However, the impact of this shift extends beyond the direct availability of information. Research suggests that social media users primarily consume news articles that are shared within their networks (Messing & Westwood, 2013). This means that when mainstream news outlets reduce their coverage of vaccination, it not only lowers the overall presence of pro-vaccine discourse but also alters the informational ecosystem by limiting the circulation of such content within online networks. As a result, vaccine-hesitant individuals may be increasingly exposed to anti-vaccine narratives, which continue to be actively shared while encountering fewer pro-vaccine perspectives. This shift in available content can contribute to changes in individual attitudes over time, reinforcing skepticism and reducing confidence in vaccination.

Finally, the structure of online communities further amplifies this effect. Smaller, tightly knit communities, such as anti-vaccine groups, tend to be more cohesive and active in disseminating their narratives (Barberá, 2020; Barberá & Rivero, 2014; Mønsted & Lehmann, 2022; Shore et al., 2016). This structural advantage enables them to dominate discussions when mainstream media disengages.

Our ABM reinforces this interpretation by demonstrating how shifts in media engagement influence the balance of the vaccine discourses on social media. Through various counterfactual scenarios, we illustrate the extent to which sustained media presence could have mitigated the dominance of anti-vaccine narratives. In Scenario 2, where we simulated a complete drop-off of news media activity, the decline in pro-vaccine content was steeper than that in the baseline scenario, emphasizing the media's role in bolstering pro-vaccine voices. Conversely, Scenarios 3 and 4, which simulated sustained or increased media engagement, demonstrated a clear mitigation of anti-vaccine dominance. These simulations suggest that an active and sustained media presence could have altered, although not entirely countered, the spread of anti-vaccine sentiment on Twitter and potentially influenced real-world vaccination rates.

This finding highlights the competitive nature of discourse on social media where dominant and counterdominant discourses continuously contest visibility and influence. Social media platforms enable actors with varying levels of power to engage in open and visible debate, creating a dynamic ecosystem in which the decline of one narrative can lead to the increased prominence of another (Pepe-Oliva & Casero-Ripollés, 2023). The absence of mainstream media coverage not only reduced the circulation of pro-vaccine discourse but also reshaped the structure of online discussions, reinforcing the dominance of alternative, anti-vaccine narratives.

A key factor in this shift is the role of highly cohesive, tightly knit communities that sustain minority discourses. Research suggests that small but highly engaged groups can exert disproportionate influence by continually sharing and amplifying their messages (Barberá & Rivero, 2014; Mønsted & Lehmann, 2022). Unlike pro-vaccine discourse, largely dependent on institutional voices and mainstream media, anti-vaccine narratives are driven primarily by decentralized networks of committed users. The persistence of these groups allows them to maintain a strong presence even when pro-vaccine discourse declines, giving the impression of a larger and more widespread opposition to vaccination than actually exists (Shore et al., 2016).

Our findings underscore the critical need for public health organizations and government agencies to maintain a proactive and sustained presence in the online information ecosystem. We have shown that such a presence would guarantee, or at least contrast, the negative effects of the informational void created by the lack of government communication via mainstream and social media. Our findings align with research demonstrating that exposure to misinformation significantly reduces the likelihood of vaccination (Cinelli et al., 2021; Gkinopoulos et al., 2022; Wilson & Wiysonge, 2020). In South Africa, vaccine hesitancy is highest among individuals who place greater trust in social media as an information source than among those who do not rely on these platforms (Burger et al., 2021; Sundani & Motloutsi, 2021). This suggests that social media is not merely a medium for discourse but also an active agent that shapes public perceptions of vaccine safety and necessity.

In addition to previous research, we have shown that the persistent presence of accurate information could actively counter misinformation. In our case study, while misinformation spread rapidly, efforts to counter it were uneven. As Burger et al. (2021) highlighted, government initiatives in South Africa have focused primarily on raising awareness of Covid-19 symptoms and preventive measures with far less emphasis on debunking vaccine-related misinformation. In contrast, other national contexts have demonstrated more strategic and diversified approaches to social media communication. Comparative research has emphasized that the effectiveness of governmental communication can be strengthened by combining instructive content, such as clear directives, with expressive messages that foster solidarity and empathy (Leong et al., 2023; Page & Hansson, 2024). Such diversified strategies may help increase public receptivity and mitigate resistance, particularly in contexts where trust in institutions is limited.

6. Limitations and Future Directions

This study also acknowledges certain limitations. First, the use of tweets strongly limits the exploration of sociodemographic variables, as metadata, such as gender, age, and specific region are missing. However, we know that Twitter users are not a random sample of the South African population. We also know that males and young people are less willing to be vaccinated in South Africa (Cooper, 2021). However, considering the nature of our data, individual-level analyses are very limited and probably faulty. For this reason, we adopted a systemic approach by focusing on macro-level dynamics. Our results should not be interpreted as representative of the public opinion dynamics in South Africa; instead, they highlight how the vaccination debate unfolded during that period and provide a quite clear picture of what a random user would have encountered if accessing Twitter and searching for information on the Covid-19 vaccine.

In addition, the categorization of tweets via machine learning, while rigorously conducted, might miss or misinterpret some of the nuances that are expressed in the texts. Although our manual validation suggests the overall reliability of the classification, some errors are undoubtedly present. Furthermore, it could be argued that at least part of the decline in pro-vaccination tweets might be explained by the increase in unclear tweets in Phase 4. While this aspect cannot be completely excluded, it also highlights another important fact. In the final phase, categorizing tweets as either supporting or opposing vaccinations was more difficult for the SVM algorithm. Because the SVM classification relies on the clarity and distinctness of the input, in this case language, this analysis shows that pro- and anti-vaccination language became more entangled during this period. In other words, if the SVM algorithm misclassified pro-vaccination messages, their content was not as clear an indication of stance, contributing to the lack of a clear contrast to the

anti-vaccination narrative. Namely, the SVM algorithm acts as a naive internet user searching for information on the vaccine and needing to understand the position expressed in the tweets that were found. Further studies should delve into the topics treated in the tweets, not only their overall stance but also their individual motivations for tweeting or interacting with other users.

In this study, we used ABM to explore counterfactual scenarios to corroborate our hypotheses. While providing valuable insights, ABM is a simplification of a complex real-world scenario. In this article, we assumed a relatively arbitrary and optimistic view of the influence that the media can have on opinions. Alternative parameters and interaction rules could be specified to simulate the influence between media and agents (e.g., Axelrod, 1997; Hu & Zhu, 2017). Each of these parameters relies on a set of assumptions about how agents interact. We chose to minimize these assumptions and to tune our model on real data. The distribution of stances in our baseline model after the first step, mirroring the empirical data, validates our procedure. However, we cannot truly know the probability that news media can influence an individual's position. It can depend on many different factors and varies among individuals. Our goal was only to explore a series of scenarios to answer the question of whether news media could have made a difference in the online debate on Covid-19 vaccination in South Africa. Although our results suggest this, we cannot provide a definitive answer. Future studies, such as in-lab and natural experiments, should address this issue.

Despite these limitations, the lessons learned from our case study highlight the broader implications of media engagement in shaping public discourse. Beyond Covid-19, similar dynamics may be observed in other health crises and policy debates where misinformation competes with evidence-based information. These challenges require a proactive, sustained commitment from governments, news organizations, public health agencies, and digital platforms to ensure that accurate, credible information remains visible and accessible. Strengthening media literacy, enhancing journalistic integrity, and fostering institutional trust are crucial steps in counteracting the spread of misinformation and reinforcing informed decision-making in public debates.

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Conflict of Interests

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Data Availability

Data are protected by X's terms of use. They can be made available upon request to the corresponding author.

LLMs Disclosure

Gemini was used for reference formatting and grammar check.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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About the Authors

Davide Morselli is senior lecturer at the Institute of Social Science of the University of Lausanne. His research is focused on processes of social influence between people and their environment, with a focus on computational methods and social media. He is co-directing with Kevin Durrheim the People–Opinion Networks (PONs) project.

Maite Beramendi holds a PhD in psychology from the University of Buenos Aires. She currently conducts research at the University of Lausanne and at the University of Buenos Aires under the National Scientific and Technical Research Council of Argentina (CONICET). Her research focuses on social norms, social mobilization, and polarization processes.

Andrés Martinez Torres is a PhD candidate in Social Sciences at the University of Lausanne. His research focuses on the use of computational methods for the study of group identity, with a particular emphasis on anti-normative groups and the manosphere.

Nnaemeka Ohamadike is a PhD candidate in applied data science at the University of Johannesburg, specialising in computational methods for detecting bias in language data. He is also a senior data analyst at Good Governance Africa. His research explores issues like bias, disinformation, human development, and governance, using data science.

Melody Sepahpour Fard is a final-year PhD candidate in data science at the Center for Research Training in Foundations of Data Science, University of Limerick. With a background in social psychology and language sciences, she conducts interdisciplinary research in computational social science, focusing on social identity, narrative construction, and social movements.

Maria Schuld leads the quantum machine learning team at Xanadu, a Canadian quantum computing startup. She received a PhD in physics from the University of KwaZulu-Natal in 2017 studying how emerging technologies enable new machine learning paradigms. When time permits, she investigates how machine learning, in turn, enables new social science research tools.