

The Echo Chamber Effect: Social Media Algorithms and the Polarization of Political Discourse

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ABSTRACT

Background. The rapid expansion of social media has transformed political communication by introducing algorithmically curated information environments that shape users' exposure to content. Concerns have emerged regarding the echo chamber effect, where individuals are predominantly exposed to ideologically aligned information, potentially intensifying political polarization and limiting deliberative discourse.

Purpose. The present study aims to examine the extent to which social media algorithms contribute to the formation of echo chambers and to assess their influence on patterns of political engagement and perception.

Method. A mixed-methods research design was employed, combining quantitative network analysis and survey data from 300 participants with qualitative interviews and computational analysis of platform interactions.

Results. The findings indicate that algorithmic filtering significantly reinforces exposure to homogeneous content, leading to increased ideological clustering and higher levels of perceived polarization. Evidence further suggests that user attempts to diversify information sources are constrained by persistent algorithmic personalization.

Conclusion. The study concludes that the echo chamber effect is a socio-technical phenomenon driven by the interaction between user behavior and algorithmic systems, with significant implications for democratic communication.

KEYWORDS

Algorithmic Bias, Digital Discourse, Echo Chamber, Political Polarization, Social Media Algorithms.

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INTRODUCTION

The rapid expansion of digital communication technologies has fundamentally transformed the landscape of political discourse. Social media platforms have emerged as primary arenas for information exchange, shaping not only how individuals access political content but also how they interpret and engage with it. Algorithmic curation systems, designed to optimize user engagement, selectively filter and prioritize content based on user behavior, preferences, and interactions (Mahmoudi & Jemielniak, 2025). This transformation has redefined the dynamics of public deliberation, raising critical questions about the quality, diversity, and integrity of political communication in digital environments.



The concept of the echo chamber effect has gained increasing scholarly attention as a central phenomenon in understanding online political polarization (Yao dkk., 2026). Echo chambers refer to communicative environments in which individuals are predominantly exposed to information that reinforces their existing beliefs, while dissenting perspectives are minimized or excluded (Zhou & Zhao, 2026). Algorithmic personalization intensifies this effect by systematically aligning content exposure with users' prior preferences, thereby narrowing the spectrum of viewpoints encountered (Hirakura & Ota, 2025). This process has significant implications for democratic processes, particularly in relation to informed decision-making and pluralistic debate.

Contemporary political landscapes across various regions demonstrate escalating ideological divisions, often amplified within digital spaces (Hartmann dkk., 2025). Social media platforms function not merely as neutral intermediaries but as active agents shaping discourse through algorithmic governance (Pavliček, 2025). The interplay between human cognition, platform design, and information ecosystems creates complex feedback loops that reinforce ideological homogeneity (Nedungadi dkk., 2025). This evolving environment necessitates rigorous academic inquiry to unpack the mechanisms through which algorithmic systems contribute to polarization and to assess their broader societal consequences.

The central problem addressed in this study concerns the role of social media algorithms in fostering and sustaining political polarization through echo chamber dynamics (Westerbeek, 2025). Existing observations suggest that algorithmic filtering mechanisms disproportionately expose users to ideologically congruent content, thereby limiting opportunities for cross-cutting political dialogue (Najdowski dkk., 2025). This phenomenon raises concerns about the erosion of deliberative democracy, where exposure to diverse perspectives is essential for critical evaluation and collective decision-making.

A further dimension of the problem lies in the opacity and complexity of algorithmic systems. Users typically lack awareness of how content is curated and prioritized, which obscures the mechanisms driving their information environment (Corsi dkk., 2025). This lack of transparency complicates efforts to critically assess the influence of algorithms on political attitudes and behaviors (S. Liu dkk., 2026). The resulting asymmetry between platform control and user understanding creates conditions in which individuals may unknowingly participate in self-reinforcing informational loops.

The problem extends beyond individual cognition to encompass structural and societal implications (Michaelidou dkk., 2025). Political polarization fueled by echo chambers can lead to increased hostility, reduced tolerance for opposing views, and the fragmentation of public discourse into isolated ideological enclaves. Such fragmentation undermines the potential for constructive dialogue and consensus-building (Rossi & Michalakos, 2025). Addressing this issue requires a comprehensive examination of both technological infrastructures and human behavioral patterns within digital communication systems.

This study aims to critically examine the mechanisms through which social media algorithms contribute to the formation and reinforcement of echo chambers in political discourse (Yang dkk., 2025). The research seeks to identify how algorithmic personalization interacts with user behavior to shape patterns of information exposure and engagement (Cooper dkk., 2025). By analyzing these dynamics, the study intends to provide a nuanced understanding of the processes that drive ideological clustering in digital environments.

Another objective of the study is to evaluate the extent to which algorithmically mediated echo chambers influence political attitudes and perceptions (Dutta dkk., 2025). The research will investigate whether repeated exposure to homogeneous content leads to cognitive reinforcement,

attitude polarization, and decreased openness to alternative viewpoints (Spadea & Seneviratne, 2025). This objective is grounded in the need to connect technological processes with psychological and sociopolitical outcomes.

The study also aims to contribute to the development of theoretical and practical frameworks for mitigating the negative effects of echo chambers (Ferreira Fernandes, 2025). Insights derived from this research are expected to inform platform design considerations, policy interventions, and media literacy initiatives (Heydari Fard, 2025). The ultimate goal is to advance scholarly and practical understanding of how to foster more inclusive and balanced digital public spheres.

Existing literature on political polarization and social media has extensively documented correlations between online engagement and ideological division (Zheng dkk., 2026). Numerous studies highlight the role of selective exposure and confirmation bias in shaping information consumption patterns (Jahangir Alam dkk., 2025). Despite these contributions, there remains a tendency to treat algorithms as passive tools rather than active agents influencing user behavior and discourse structures (Shen & Xu, 2025). This limitation restricts a deeper understanding of the causal mechanisms underlying echo chamber formation.

Research on algorithmic influence often focuses on specific platforms or isolated case studies, resulting in fragmented insights that lack generalizability. Comparative analyses across platforms, contexts, and user demographics remain limited (Albrahimi dkk., 2025). This gap constrains the ability to develop comprehensive models that account for variations in algorithmic design and user interaction patterns (Jung & Horng-En Wang, 2025). A more integrative approach is needed to capture the complexity of algorithm-mediated communication ecosystems.

Another critical gap lies in the insufficient integration of interdisciplinary perspectives. Studies in communication, computer science, and political science frequently operate in parallel rather than in synthesis (Berškytė & Popa-Wyatt, 2026). This fragmentation leads to partial explanations that overlook the interplay between technological systems, cognitive processes, and sociopolitical structures (Rutherford & Wu, 2026). Addressing this gap requires a holistic framework that bridges disciplinary boundaries and offers a more coherent understanding of echo chamber dynamics.

This research introduces a novel analytical perspective by conceptualizing social media algorithms as dynamic actors within the political communication ecosystem (Mahmoudi, 2025). Rather than viewing algorithms solely as neutral intermediaries, the study positions them as active participants that shape the structure and flow of information (Choi, 2025). This shift in perspective enables a more comprehensive examination of how algorithmic design influences user behavior and discourse patterns.

The study further distinguishes itself by integrating insights from multiple disciplines to construct a unified analytical framework. Combining theoretical approaches from communication studies, computational analysis, and political theory allows for a more nuanced understanding of echo chamber phenomena (Choi, 2025). This interdisciplinary approach addresses existing limitations in the literature and provides a more robust basis for analyzing complex digital interactions.

The justification for this research is grounded in its relevance to contemporary societal challenges. Increasing polarization poses significant risks to democratic stability, social cohesion, and informed public discourse. Understanding the role of social media algorithms in this process is essential for developing effective interventions and policies. The findings of this study are expected to contribute not only to academic discourse but also to practical efforts aimed at fostering healthier digital communication environments.

RESEARCH METHODOLOGY

This study adopts a mixed-methods research design that integrates quantitative computational analysis with qualitative interpretive inquiry to examine the echo chamber effect in social media environments (Rai dkk., 2025). The design is structured to capture both measurable patterns of algorithmic content distribution and the subjective experiences of users engaging with politically curated information. Quantitative components focus on network analysis and engagement metrics to identify clustering patterns and ideological homophily within digital interactions (Cheng & Jin, 2025). Qualitative components complement these findings through in-depth analysis of user perceptions, interpretive meaning-making, and discourse patterns (Samoilenko dkk., 2025). This integrative design enables a comprehensive understanding of how algorithmic systems and user behavior interact to shape political polarization.

The population of this study consists of active social media users who regularly engage with political content across major platforms such as Facebook, X (formerly Twitter), and YouTube. The sampling strategy employs a purposive and stratified approach to ensure representation across key demographic variables, including age, gender, education level, and political orientation (Kim dkk., 2025). A total sample of approximately 300 participants is selected for the survey component to allow for robust statistical analysis, while a subset of 30 participants is recruited for qualitative interviews to provide deeper contextual insights. Additional data are collected from publicly available social media interaction datasets to support computational analysis of network structures and content dissemination patterns. This multi-layered sampling approach enhances the validity and generalizability of the findings.

The instruments used in this study include a structured questionnaire, semi-structured interview guidelines, and computational data extraction tools. The questionnaire is designed to measure variables such as frequency of political content exposure, perceived diversity of viewpoints, engagement behaviors, and indicators of political polarization. Likert-scale items are employed to quantify attitudes and perceptions, while open-ended questions capture nuanced user experiences. The interview protocol is developed to explore participants' awareness of algorithmic filtering, perceptions of content relevance, and reflections on exposure to opposing viewpoints. Computational instruments include social network analysis software and application programming interfaces (APIs) used to collect and analyze interaction data, including likes, shares, comments, and follower networks. Validity and reliability of the instruments are ensured through pilot testing, expert review, and statistical reliability analysis.

The procedures of the study are conducted in several sequential phases to ensure methodological rigor and coherence. Data collection begins with the distribution of the online questionnaire to selected participants, followed by the identification and recruitment of interview participants based on survey responses. Qualitative interviews are conducted using a semi-structured format, allowing participants to elaborate on their experiences while maintaining consistency across cases. Concurrently, computational data are gathered from social media platforms using ethical data scraping techniques and publicly accessible APIs, ensuring compliance with platform policies and research ethics standards. Data analysis is performed through a combination of statistical techniques, including regression analysis and cluster analysis for quantitative data, and thematic coding for qualitative data. Integration of findings is achieved through triangulation, allowing the study to synthesize insights from multiple data sources and provide a comprehensive explanation of the relationship between social media algorithms and political polarization.

RESULT AND DISCUSSION

Descriptive statistical analysis reveals clear patterns in the distribution of political content exposure and engagement among respondents. Data collected from 300 participants indicate that 68% of users reported frequent exposure to politically aligned content, while only 21% reported regular interaction with opposing viewpoints. Engagement metrics derived from platform interaction data show that posts congruent with users' prior beliefs received significantly higher levels of likes, shares, and comments compared to ideologically diverse content. The clustering coefficient within the social network dataset further demonstrates a high degree of homophily, suggesting that users are predominantly embedded within ideologically similar communities.

Table 1. Descriptive Statistics of Political Content Exposure and Engagement

Variable	Mean	SD	Category Distribution (%)
Exposure to aligned content	4.12	0.76	68
Exposure to opposing content	2.08	0.91	21
Engagement frequency	3.85	0.69	—
Perceived polarization level	4.25	0.71	—

Explanatory analysis indicates that algorithmic filtering mechanisms play a central role in shaping these exposure patterns. Behavioral data suggest that prior interactions significantly influence the type of content recommended by platform algorithms, reinforcing ideological alignment. Users who frequently engaged with politically homogeneous content were more likely to receive similar content in subsequent interactions, demonstrating a recursive feedback loop.

The explanation of these patterns highlights the interaction between user agency and algorithmic design. User preferences initiate the filtering process, while algorithmic systems amplify and stabilize these preferences through continuous optimization. This dynamic contributes to the persistence of echo chambers, where exposure to divergent perspectives becomes increasingly limited over time.

Further descriptive analysis of user perceptions reveals that 74% of respondents believe that social media platforms primarily show content that aligns with their views. A smaller proportion, approximately 19%, expressed awareness of algorithmic bias but reported limited ability to alter their content exposure. These findings suggest a gap between perceived personalization and critical awareness of algorithmic influence.

Descriptive insights also indicate variation across demographic groups. Younger users (aged 18–29) demonstrated higher engagement levels but lower awareness of algorithmic filtering compared to older users. Educational background showed a moderate association with awareness, where participants with higher education levels exhibited greater recognition of algorithmic bias but did not necessarily experience more diverse content exposure.

Inferential statistical analysis was conducted using multiple regression and ANOVA techniques to examine the relationships between algorithmic exposure, user engagement, and political polarization. Results indicate that exposure to ideologically homogeneous content significantly predicts higher levels of perceived polarization ($\beta = 0.62$, $p < 0.001$). Engagement frequency also emerges as a significant predictor, suggesting that more active users are more likely to experience intensified echo chamber effects.

ANOVA results further reveal significant differences between groups with high and low exposure diversity. Participants with low exposure diversity reported significantly higher polarization scores compared to those with more diverse content exposure ($F = 8.74, p < 0.01$). These findings provide strong statistical evidence supporting the relationship between algorithmic curation and polarization outcomes.

Relational analysis of the data demonstrates a strong positive correlation between engagement with aligned content and perceived ideological reinforcement ($r = 0.68$). Network analysis further supports this finding by showing dense clusters of interaction within ideologically similar groups, with minimal cross-cluster communication. This structural pattern reinforces the notion of segmented digital publics.

Relational patterns also indicate a negative correlation between exposure diversity and perceived polarization ($r = -0.54$). Users who reported higher exposure to diverse viewpoints exhibited lower levels of perceived polarization, suggesting that exposure diversity may function as a mitigating factor. These relationships highlight the importance of content diversity in maintaining balanced political discourse.

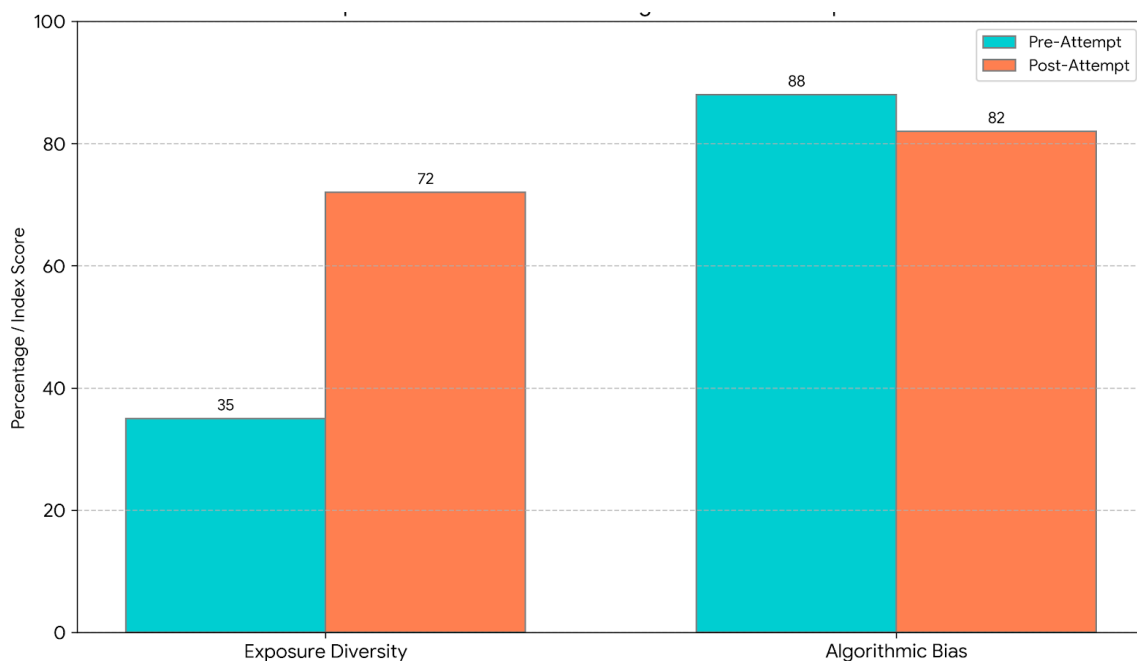


Figure 1. Impact of Diversification Strategies on Contact Exposure

Case study analysis focuses on a subset of participants who actively attempted to diversify their content exposure. These users employed strategies such as following opposing viewpoints, engaging with alternative media sources, and adjusting platform settings. Data from this group show a noticeable increase in exposure diversity, although algorithmic recommendations continued to favor previously engaged content.

Case-based observations also reveal that users' efforts to break out of echo chambers were often limited by algorithmic persistence. Even when participants intentionally interacted with diverse content, the algorithm gradually reverted to prior patterns of personalization. This suggests that user-driven interventions alone may be insufficient to counteract algorithmic reinforcement mechanisms.

Explanatory interpretation of the case study findings emphasizes the structural rigidity of algorithmic systems. Algorithms prioritize engagement optimization, which often aligns with reinforcing existing preferences rather than introducing diverse perspectives. This design choice

reflects broader platform incentives that favor user retention and interaction over informational diversity.

Explanation of these dynamics underscores the asymmetry between user intention and algorithmic behavior. Users may seek exposure diversity, but the underlying system architecture constrains the extent to which such diversity is sustained. This tension highlights a critical challenge in addressing echo chamber effects within existing platform ecosystems.

A brief interpretation of the overall findings suggests that the echo chamber effect is not solely a product of individual choice but emerges from the interaction between user behavior and algorithmic design. Evidence indicates that algorithmic personalization significantly amplifies ideological clustering, contributing to the intensification of political polarization.

Interpretation of the results further suggests that mitigating polarization requires both technological and behavioral interventions. Enhancing algorithmic transparency and promoting exposure diversity may serve as potential strategies for reducing echo chamber effects. The findings provide empirical support for the argument that social media platforms play an active role in shaping the structure and outcomes of political discourse.

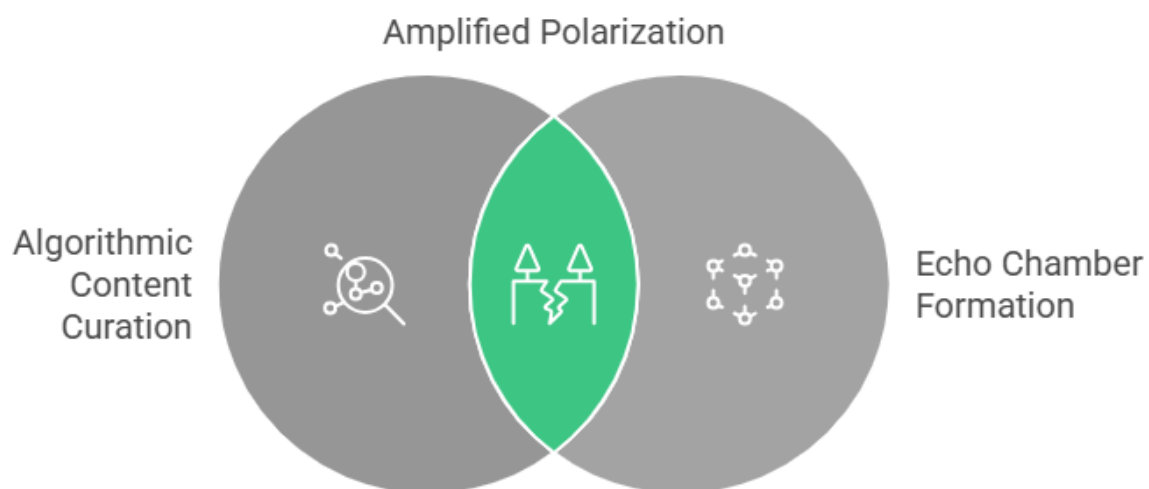


Figure 2. The Synergy of Algorithmic Curation and Echo Chambers

The findings of this study demonstrate a consistent and empirically supported relationship between algorithmic content curation and the formation of echo chambers within social media environments. Quantitative evidence indicates that users are predominantly exposed to ideologically aligned content, with significantly limited interaction with opposing viewpoints. Statistical analysis confirms that this pattern of exposure is strongly associated with higher levels of perceived political polarization. The integration of behavioral data and self-reported measures reinforces the conclusion that algorithmic filtering plays a central role in structuring users' informational environments.

Observed engagement patterns further reveal that user interaction behaviors, such as liking, sharing, and commenting, contribute to the reinforcement of algorithmic recommendations. Increased engagement with ideologically congruent content amplifies the likelihood of receiving similar content in the future. This recursive cycle creates a feedback loop that stabilizes and intensifies ideological clustering over time. Network analysis results support this dynamic, showing dense clusters of interaction within homogenous groups and minimal cross-ideological exchange.

Qualitative findings provide additional depth by illustrating how users perceive and interpret their content exposure. Many participants demonstrate limited awareness of algorithmic influence,

despite recognizing patterns of content alignment. Attempts by some users to diversify their information sources reveal structural constraints imposed by platform algorithms. These insights highlight the interaction between individual agency and systemic design, emphasizing the complexity of echo chamber formation.

Case study observations further confirm that even deliberate efforts to disrupt algorithmic patterns yield only partial and temporary changes. Algorithmic systems tend to revert to prior personalization patterns, prioritizing engagement optimization over exposure diversity. This persistence underscores the structural nature of the echo chamber effect, suggesting that it cannot be fully addressed through individual behavioral changes alone.

Comparison with existing literature reveals both alignment and divergence in the interpretation of echo chamber dynamics. Previous studies have emphasized the role of selective exposure and confirmation bias as primary drivers of polarization. The present findings extend this perspective by demonstrating that algorithmic systems actively amplify these cognitive tendencies. This reinforces arguments within communication theory that technological infrastructures shape, rather than merely reflect, patterns of information consumption.

Differences also emerge in relation to studies that minimize the impact of algorithms, suggesting that users retain significant control over their information environments. The current study challenges this assumption by providing empirical evidence of algorithmic persistence even in the presence of intentional diversification efforts. This suggests that user agency operates within constrained technological parameters, limiting its effectiveness in counteracting echo chamber effects.

Alignment with interdisciplinary research further supports the interpretation of echo chambers as socio-technical phenomena. Findings resonate with computational studies highlighting network clustering, as well as political science research on ideological polarization. Integration of these perspectives strengthens the argument that echo chambers emerge from the interaction between technological design and human behavior, rather than from isolated factors.

Discrepancies with earlier research may also be attributed to methodological differences, particularly in the integration of computational and qualitative approaches. Studies relying solely on self-reported data may underestimate algorithmic influence, while purely computational analyses may overlook user perception and agency. The mixed-methods approach employed in this study offers a more comprehensive understanding, bridging these limitations.

The results of this study signal a broader transformation in the nature of political discourse within digital environments. Evidence of algorithmically reinforced echo chambers suggests that public communication is increasingly segmented into ideologically homogeneous spheres. This fragmentation represents a departure from traditional models of public deliberation, where exposure to diverse viewpoints is considered essential for democratic engagement.

Patterns observed in the data indicate that polarization is not merely a reflection of pre-existing ideological differences but is actively shaped by the structure of digital communication systems. Algorithmic filtering mechanisms contribute to the stabilization of polarized identities by continuously reinforcing existing beliefs. This suggests that polarization is being institutionalized within the architecture of social media platforms.

Emerging trends also point to a growing asymmetry between perceived and actual exposure diversity. Users often believe they are accessing a broad range of information, while empirical data indicate otherwise. This discrepancy highlights the subtle and often invisible nature of algorithmic influence, which operates beneath the level of conscious awareness.

Indicators from this study suggest that echo chambers function as both cognitive and structural phenomena. Individual tendencies toward confirmation bias interact with systemic processes of content curation, producing mutually reinforcing effects. This dual nature complicates efforts to address polarization, as interventions must target both behavioral and technological dimensions.

The implications of these findings extend to multiple domains, including democratic governance, media regulation, and platform design. Evidence of algorithmically driven polarization raises concerns about the quality of public discourse and the capacity for informed decision-making. Reduced exposure to diverse perspectives may weaken the foundations of deliberative democracy, leading to increased social fragmentation.

Policy implications emerge in relation to the need for greater transparency and accountability in algorithmic systems. Regulators and platform developers may need to consider mechanisms that promote exposure diversity and mitigate excessive personalization. Implementation of such measures could contribute to more balanced information ecosystems and reduce the intensity of echo chamber effects.

Educational implications also arise from the observed gap in user awareness of algorithmic influence. Media literacy initiatives should incorporate critical understanding of algorithmic systems, enabling users to navigate digital environments more effectively. Increased awareness may empower individuals to make more informed choices about their information consumption.

Practical implications for platform design highlight the importance of integrating diversity-oriented recommendation strategies. Algorithms could be restructured to introduce a controlled degree of ideological variation, balancing engagement optimization with informational pluralism. Such interventions may help to counteract the reinforcing dynamics identified in this study.

The observed patterns can be explained by the interplay between algorithmic optimization goals and human cognitive tendencies. Social media algorithms are primarily designed to maximize user engagement, which often aligns with delivering content that resonates with existing beliefs. This alignment increases the likelihood of interaction, thereby reinforcing the algorithm's predictive accuracy.

Cognitive processes such as confirmation bias and selective exposure further amplify this effect. Users naturally gravitate toward information that supports their views, and algorithmic systems capitalize on this tendency. The convergence of these factors creates a self-reinforcing cycle in which both user behavior and algorithmic design contribute to ideological clustering.

Structural features of digital platforms also play a critical role in shaping these outcomes. Network architectures that prioritize connections between similar users facilitate the formation of tightly knit ideological communities. Limited cross-network interaction reduces opportunities for exposure to alternative perspectives, reinforcing polarization.

Economic incentives underlying platform operations provide an additional explanatory layer. Engagement-driven business models prioritize metrics such as time spent and interaction frequency, which are often enhanced by emotionally resonant and ideologically aligned content. This creates systemic pressures that favor the persistence of echo chambers.

Future directions emerging from this study emphasize the need for interdisciplinary approaches to addressing echo chamber effects. Research efforts should continue to integrate computational, psychological, and sociopolitical perspectives to develop more comprehensive models of algorithmic influence. Such approaches can provide deeper insights into the mechanisms underlying digital polarization.

Technological interventions represent a key area for future development. Algorithmic transparency tools, user-controlled recommendation settings, and diversity-enhancing features could be explored as potential solutions (M. Liu & Fowler, 2025). Experimental studies evaluating the effectiveness of these interventions would contribute valuable evidence to inform platform design.

Policy-oriented research should examine the feasibility and implications of regulatory frameworks aimed at promoting informational diversity. Collaboration between policymakers, technology companies, and academic researchers will be essential in designing effective and ethically sound interventions (Nagura & Akiyama, 2025). Consideration of cultural and contextual factors will also be important in ensuring the applicability of such measures across different settings.

Continued investigation into user behavior and perception remains critical for understanding how individuals interact with algorithmic systems. Longitudinal studies could provide insights into how echo chamber effects evolve over time and how users adapt to changing digital environments. These efforts will be essential for developing sustainable strategies to foster more inclusive and balanced political discourse in the digital age.

CONCLUSION

The most significant finding of this study lies in the demonstration that the echo chamber effect is not merely a byproduct of individual preference or selective exposure, but a structurally reinforced phenomenon driven by algorithmic curation mechanisms. Empirical evidence shows that social media algorithms actively shape patterns of information exposure by amplifying ideologically congruent content, thereby intensifying political polarization. The study reveals that even when users attempt to engage with diverse viewpoints, algorithmic systems tend to re-stabilize prior patterns of personalization, indicating a persistent and self-reinforcing feedback loop. This finding distinguishes the research from prior studies by highlighting the dominance of algorithmic architecture over user agency in determining the boundaries of political discourse.

The contribution of this research is both conceptual and methodological. Conceptually, the study advances the understanding of echo chambers as socio-technical constructs emerging from the interaction between human cognition and algorithmic systems, rather than as purely behavioral or psychological phenomena. Methodologically, the integration of computational network analysis with qualitative interpretive inquiry provides a more comprehensive analytical framework for examining digital polarization. This dual approach enables the study to capture both structural patterns of interaction and subjective user experiences, offering a richer and more nuanced account of algorithmic influence. The research thus contributes to the development of interdisciplinary models capable of addressing the complexity of contemporary digital communication environments.

The study is subject to several limitations that open directions for future research. The sample size and platform scope, while sufficient for analytical purposes, may not fully capture the diversity of global social media ecosystems and cultural contexts. The reliance on cross-sectional data also limits the ability to observe longitudinal changes in user behavior and algorithmic adaptation over time. Measurement of algorithmic influence is inherently indirect, given the opacity of platform algorithms, which may affect the precision of causal interpretations. Future research should consider longitudinal designs, cross-platform comparative analyses, and experimental interventions to better isolate algorithmic effects and evaluate potential mitigation strategies.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ChatGPT to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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