Sarcouncil Journal of Humanities and Cultural Studies

ISSN(Online): 2945-3658

Volume- 05| Issue- 01| 2026

Review Article **Received:** 10-01-2026 | **Accepted:** 05-02-2026 | **Published:** 19-02-2026

Leveraging Behavioral Analytics to Prevent Lone-Actor Terrorism in the United States: A Scoping Review

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Abstract: Lone-actor terrorism poses a persistent threat to homeland security in the United States, challenging traditional counterterrorism approaches that rely on group-based detection and ideological profiling. This scoping review examines how behavioral analytics have been applied to understanding and preventing lone-actor terrorism in the U.S. context. Guided by PRISMA-ScR principles, nine peer-reviewed studies published between 2019 and 2025 were synthesized using a thematic approach. The findings indicate that lone-actor violence is best understood as a grievance-fueled and behaviorally structured process rather than an ideologically stand-alone phenomenon. Behavioral indicators such as grievance escalation, preparatory actions, behavioral leakage, and temporal windows for intervention were consistently identified, although significant data and observability constraints remain. The review highlights the need for grievance-centered, ethically governed, and human-centered behavioral analytics to strengthen U.S. lone-actor terrorism prevention efforts.

Keywords: Lone-actor terrorism, Behavioral analytics, Grievance-fueled violence, Threat assessment, United States.

INTRODUCTION

Lone-actor terrorism, characterized by individuals who plan and execute acts of violence without direct orders or substantial material assistance from an organized group, poses a distinct and evolving threat to national security in the United States (Altay *et al*., 2020). This form of terrorism is particularly challenging to detect because of the absence of traditional organizational structures, making conventional counterterrorism strategies less effective (Tillett, 2021). The prevalence of lone-actor terrorism has increased rapidly over the past two decades, with notable incidents, including the 2017 Las Vegas mass shooting (Altay *et al*., 2020). , Other cases, including the 2009 Fort Hood shooting, the 2013 Boston Marathon bombing, the 2016 Orlando nightclub attack, and the 2017 New York City truck attack, further underscore the devastating impact and diverse motivations behind such acts (Altay *et al*., 2020; Clemmow *et al*., 2022). Even the 2025 Charlie Kirk murder exemplifies the complex and often unpredictable nature of lone-actor violence, highlighting the urgent need for innovative detection and prevention strategies.

Despite their independent nature, lone actors often show observable behavioral patterns and pre-attack indicators that, if identified and analyzed effectively, could offer critical intervention points (Gill *et al*. 2022). Nevertheless, current intelligence processes overly rely on manual identification and monitoring of potential threats, a method increasingly overwhelmed by the growing diversity and number of individuals spreading extremist views both on and offline (Ateş, 2020). This gap requires a shift towards a more proactive and data-driven approach capable of identifying subtle behavioral anomalies indicative of radicalization and impending violent acts (Adiarte *et al*., 2025). Consequently, behavioral analytics offers a favorable avenue to address this challenge by employing computational techniques to analyze vast datasets and discern patterns that might otherwise go unnoticed by manual identification (Subrahmanyam, 2025). This involves examining an individual's digital footprint, financial transactions, social interactions, and other publicly available data to construct a comprehensive profile of their potential risk (Altay *et al*., 2020). Specifically, this approach moves beyond traditional intelligence gathering by leveraging algorithms and machine learning to identify deviations from normal behavior, yet it has received little attention in counter-terrorism research efforts. Against this backdrop, this review examines the current state of behavioral analytics in preventing lone-actor terrorism in the United States by identifying key methodologies, challenges, and future directions.

METHODS

This scoping review systematically mapped the existing literature on leveraging behavioral analytics to prevent lone-actor terrorism in the United States. The methodology is guided by the updated framework proposed by Arksey & O'Malley (2005), which is ideal for identifying key

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DOI- https://doi.org/10.5281/zenodo.18703365

concepts, determining the extent of available research, and pinpointing gaps in knowledge.

Search Strategy

A comprehensive search strategy will be developed, utilizing a combination of keywords such as "lone-actor terrorism," "behavioral analytics," "radicalization," "prevention," "detection," and "United States." Boolean operators and truncation will be used to optimize the search results. The following electronic databases will be systematically searched: PubMed, Scopus, Web of Science, PsycINFO, Criminal Justice Abstracts, and the Social Science Citation Index. To capture relevant grey literature, Google Scholar, government reports (e.g., Department of Homeland Security, FBI) were consulted. Searches were limited to studies published from 2019 to 2025 to focus on contemporary research.

Inclusion Criteria

Studies were included if they focused on lone-actor terrorism, discussed the application of behavioral analytics (including computational methods, machine learning, or AI) for prevention or detection, were relevant to the U.S. context, and were peer-reviewed articles, dissertations, conference proceedings, or reputable gray literature providing empirical data or conceptual insights.

Exclusion Criteria

Studies were excluded if they primarily addressed group-based terrorism, discussed behavioral analytics outside the context of terrorism prevention, were opinion pieces, lacked sufficient detail, or were duplicated.

Data Extraction and Synthesis Method

Data extraction followed a structured approach aligned with the review's objective. For each included study, relevant information was systematically recorded, including author(s), year of publication, study aim, geographic focus, sample characteristics, methodological approach, and key findings related to lone-actor terrorism. For synthesis, a thematic analysis approach was employed (Squires, 2023). Extracted data were iteratively reviewed to identify recurring patterns and conceptual themes related to lone-actor behavior, grievance pathways, preparatory and leakage behaviors, temporal escalation, and ideological influences. Thematic integration emphasized convergence and divergence across studies, as well as the practical and ethical implications of applying behavioral analytics for lone-actor violence prevention in the United States. This approach allowed for a narrative synthesis of the findings while maintaining transparency and reproducibility.

RESULTS

Following the study selection, nine studies were included in the scoping review. The included literature spans 2019–2025 and reflects a methodologically diverse evidence base, including quantitative empirical studies, qualitative analyses, structured threat assessment applications, and conceptual policy-orientated work. Most studies examined lone-actor terrorism in the United States, either exclusively or comparatively, with several incorporating Western European or international cases for contextual contrast.

The sample sizes of the included studies ranged from single-case qualitative analyses to large retrospective datasets exceeding 180 offenders. Data sources primarily relied on open-source information, archival datasets, and publicly available records. No study employed prospective or real-time behavioral analytics in operational settings. Across the included studies, behavioral analysis was operationalized through multiple lenses, including:

1. Grievance and identity-based frameworks,
2. Behavioral sequencing and temporal analysis,
3. Structured professional judgment tools,
4. Ideological content analysis, and
5. Weapon acquisition timelines.

Despite the variation in approach, all studies addressed behavioral processes relevant to lone-actor pathways to violence, aligning with the review objective of examining how behavioral analytics may inform prevention strategies.

Table 1. Characteristics of included studies (n=9)

Study/Year	Country/ Sample	Study Aim	Methodology	Behavioral /Analytical Focus	Key Findings/ Implications
Clemmow, C., Gill, P., Bouhana, N., Silver,	USA; 183 offenders (68 lone-actor terrorists, 115	To examine whether lone-actor terrorists and mass murderers can be	Quantitative; cluster and bivariate analyses using	Propensity, situation, preparatory actions, leakage,	Found substantial overlap between lone-actor terrorists and mass murderers;

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J., & Horgan, J. (2020)	mass murderers)	disaggregated along dimensions relevant to threat assessment	Risk Analysis Framework (RAF)	social networks	no profile exclusively classified one type; supports dynamic, grievance-fueled - fueled behavioral model. Implications for threat assessment include integrating multiple behavioral dimensions rather than relying on typologies.
Altay, A., Baykal-Gürsoy, M., & Hemmer, P. (2020)	International; 190 lone actors	To analyze behavioral associations and temporal changes in lone-actor terrorism	Quantitative; association rule mining (a-posteriori analysis)	Behavioral characteristics, ideology, incident-scene behavior	Identified statistically significant behavioral chains and temporal patterns; pre-9/11 actors often radicalized locally, post-9/11 actors more diverse; emphasizes temporal windows for intervention.
Ganor, B. (2019)	Conceptual; global	To explore the implications of AI and big data for counterterrorism	Conceptual / policy analysis	AI, big data, counterterrorism ethics	Discussed AI's potential in threat detection alongside ethical concerns (bias, privacy, civil liberties); highlights need for governance in behavioral analytics.
Brugh, C. S., Desmarais, S. L., & Simons-Rudolph, J. (2020)	USA & Western Europe; 77 lone actors (35 US, 38 EU)	To evaluate the TRAP-18 tool for identifying lone-actor terrorist risk	Quantitative; structured professional judgment ratings using public information	TRAP-18 indicators: grievance, pathway, ideological framing, etc.	Many TRAP-18 items are difficult to observe publicly; only four indicators consistently rated; suggest operational limitations of threat assessment tools in open-source environments.
Windisch, B. (2021)	USA; post-9/11 lone actors	To explore the role of hegemonic masculinity in radicalization and attacks	Qualitative; thematic analysis	Gender identity, grievance, stressors, prior violence	Identified identity threats and masculinity-related stressors as catalysts for escalation; underscores grievance as an emotionally charged driver of lone-actor violence.
Wilson, C., Dziwulski, M., Renner, E., & Smylie, J. (2025)	Single case (Christchurch terrorist, NZ)	To examine the role of ideology in motivating lone-actor terrorism	Longitudinal qualitative content analysis of online posts	Ideology, identity formation, moral disengagement, signaling behavior	Ideology is crucial in structuring pathways to attack; interacts with grievance and identity; supports multi-dimensional

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					behavioral models over ideology-only frameworks.
Williams, T. J. V., Tzani, C., & Ioannou, M. (2024)	USA; mass shootings by lone actors	To examine the time interval between firearm acquisition and attack	Quantitative; archival analysis	Temporal delay, attack planning, firearm acquisition	Average delay 54 days between legal firearm acquisition and attack; confirms structured escalation and highlights actionable windows for intervention.
Rose, M., & Morrison, J. (2021)	USA; IS-inspired lone-actor terrorism court cases	To explore leakage as a warning behavior in lone-actor terrorists	Quantitative /exploratory archival court record analysis	Leakage behavior: type, audience, channel, online presence	Leakage frequently expressed to the public and co-conspirators, online or verbally; significantly associated with FBI interaction and attack initiation; no association with mental health; emphasizes behavioral observables as early warning signals for intervention.
Kemper, B. (2022)	Conceptual; global	To critically assess AI and "stochastic terrorism" as a tool against lone-actor violence	Conceptual /policy analysis	AI, machine learning, stochastic terrorism, ethics	Explored AI and ML for detecting media-driven lone-actor violence; highlighted ethical, legal, and bias challenges; emphasized limits of using AI for predictive labeling; underlines the need for transparent, responsible behavioral analytics.

THEMATIC SYNTHESIS OF FINDINGS

Grievance as a Central Behavioral Driver

A major theme identified across the literature is the focus of grievance in shaping lone-actor motivations to violence. For instance, Clemmow *et al*. (2020) argued that lone-actor terrorists and mass murderers cannot be meaningfully separated into distinct behavioral categories. Instead, they occupy intertwined spaces within what they termed as "lone-actor grievance-fueled violence". Their findings show that behavioral indicators such as stressors, preparatory actions, leakage, and social isolation cut across ideological labels, thereby challenging systematic distinctions that have traditionally guided counterterrorism practice.

This grievance-focused understanding is further reinforced by Windisch (2021), who situated lone-actor terrorism within broader identity and masculinity crises. By showing how perceived failures to meet hegemonic masculine norms interact with personal grievances and prior to gender-based violence. The study framed grievance escalation as a socially embedded and emotionally charged process rather than purely an ideological one. To complement this, Rose and Morrison (2021) highlighted leakage behavior as a behavioral manifestation of grievance. Their review of IS-inspired lone-actor cases in the

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United States found that individuals frequently disclosed aspects of their intent or support for violence, either online or to specific social contacts. They further found that leakage was closely associated with FBI interaction and attack initiation, reinforcing the idea that grievance expression can precede and predict violent action. This implies that grievance operates as a foundational behavioral driver that often outweighs ideological commitment, underscoring the importance of monitoring grievance-related behaviors in prevention strategies.

Behavioral Sequencing and Escalation Pathways

Beyond identifying key drivers of lone-actor terrorism, several of the studies highlighted how lone-actor violence unfolds through detectable behavioral sequences. Altay *et al*. (2020) revealed that lone-actor behaviors are not casually shared but instead form statistically significant association links that vary by ideology and historical period. They further argued that their use of association rule mining reveals behavioral pathways from radicalization to attack execution and post-attack behavior, underscoring the structured nature of escalation.

Similarly, Williams *et al*. (2024) introduced a temporal dimension by examining the delay (an average of 54-day interval) between legal firearm acquisition and attack perpetration in U.S. mass shootings. The result of the temporal dimension provides concrete evidence that lone-actor violence is rarely impulsive, creating identifiable opportunities for intervention.

Rose and Morrison (2021) further showed that leakage behaviors occur in predictable patterns, with different types of leakage targeting different audiences depending on the stage of attack planning. In other words, lone-actor terrorism escalation occurs over time and presents identifiable windows for intervention. Hence, the urgent need to leverage behavioral analytics in its prevention in the United States.

Ideology alone is Insufficient

Although some literatures downplay ideology, the findings reviewed here suggest a more nuanced role. For instance, Wilson *et al*. (2025) revealed how ideology can meaningfully shape behavior, motivation, and justification for lone-actor violence over time. Further, their longitudinal analysis of online content demonstrated how ideological narratives influence identity formation, moral disengagement, and signaling behaviors that precede violence.

Nevertheless, ideology alone has been found to not account for mobilization. Instead, it operates in tandem with grievance, identity threats, and situational stressors. This interactional role aligns with Clemmow *et al*.'s (2020) dynamic model, which positioned ideology as one component within a broader behavioral process rather than a standalone cause. Hence, it is imperative for policy makers and practitioners to pay critical attention to both the ideological and personal factors that drive lone-actor violence in prevention efforts.

Threat Assessment, Observability Constraints and Ethical Issues in Behavioral Analytics

The findings also revealed that, while behavioral indicators are theoretically identifiable, practical observability remains limited. For instance, Brugh *et al*. (2020) found that many Terrorist Radicalization Assessment Protocol 18 (TRAP-18) indicators are difficult to code using public information, with only a small subset, such as grievance and ideological framing consistently being observable. Rose and Morrison (2021) further underscored this point by showing that leakage often occurs in private or selective channels, highlighting the limitations of relying solely on open-source or publicly available data.

In addition, the findings highlighted how ethical and governance considerations compound these challenges. For instance, Ganor (2019) situated AI-driven counterterrorism within debates about balancing effectiveness with democratic values, noting that advanced analytics may enhance detection but also raise concerns about privacy, bias, and accountability. Similarly, Kemper (2022) argued that AI and machine learning tools applied to stochastic terrorism raise significant ethical concerns, particularly around false attribution, legal causation, and the potential for disproportionate state responses. These findings highlight the necessity of embedding ethical safeguards alongside analytical tools.

DISCUSSION

This review demonstrates that behavioral analytics offer substantial potential for improving lone-actor terrorism prevention in the United States, but only when grounded in process-oriented and ethically governed models. The reviewed evidence consistently challenged ideology-centric approaches and static offender profiling. Instead, it supports an understanding of lone-actor terrorism

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as a dynamic behavioral process influenced by grievance, identity threats, behavioral leakage, and situational opportunity (Clemmow *et al*., 2020; Windisch, 2021; Rose & Morrison, 2021).

Furthermore, the identification of behavioral sequences and temporal delays suggests that lone-actor attacks are often preceded by detectable patterns rather than spontaneous acts (Altay *et al*., 2020; Williams *et al*., 2024; Rose & Morrison, 2021). This has direct implications for prevention, as it shifts the focus from predicting who will offend to detecting when and how escalation will occur.

The review also revealed significant constraints. The heavy reliance of most studies on retrospective data limits their applicability to real-time prevention. Also, the difficulty of observing key indicators using open-source information undermines the operational utility of existing threat assessment frameworks (Brugh *et al*., 2020). This implies that, without an integrated and multi-sourced data system, behavioral analytics risk being incomplete or misleading.

Lastly, ethical considerations including privacy, bias, and misuse of AI tools were found to complicate effective implementation. As Ganor (2019) and Kemper (2022) noted, expanding behavioral surveillance without clear safeguards may violate civil liberties and erase public trust. Therefore, effective implementation cannot be pursued independently of governance and accountability.

IMPLICATIONS OF FINDINGS FOR LONE-ACTOR VIOLENCE PREVENTION

The findings of this review imply that U.S. lone-actor violence prevention strategies should move decisively toward grievance-centered behavioral models. This is because, by prioritizing grievance escalation, identity stressors, and behavioral leakage, analysts may better capture early warning signals that cut across ideological categories.

Furthermore, the gaps between preparatory behaviors and attacks are an indication that behavioral analytics can support early intervention, particularly when weapon acquisition, online activity, leakage behavior and situational stressors are analyzed together. Worth noting is that these tools must function as decision-support mechanisms within multidisciplinary threat assessment teams rather than as autonomous predictive systems.

Finally, ethical governance must be included from the beginning of everything. This is because, without transparent oversight and bias mitigation strategies, behavioral analytics may produce false narratives and unb unbalanced scrutiny, undermining both effectiveness and legitimacy.

LIMITATIONS

Several limitations should be considered when interpreting the findings of this scoping review. First, the review is based on a relatively small number of studies, reflecting the narrow but emerging evidence based on behavioral analytics and lone-actor terrorism. Also, this study did not assess the quality or risk of bias of individual studies but rather focused instead on mapping and synthesizing the available evidence.

CONCLUSION

This review has highlighted that behavioral analytics offer a promising but underdeveloped approach to preventing lone-actor terrorism in the United States. The reviewed literature consistently revealed how lone-actor violence emerges through grievance-fueled and temporally sequenced behavioral processes rather than through ideology alone. While existing studies provide valuable insights into escalation pathways, preparatory behaviors, and intervention windows, significant gaps were also noted regarding prospective validation, data integration, and ethical governance of analytics tools. To advance prevention efforts, future research and practice must adopt grievance-centered, multi-sourced, and ethically grounded behavioral analytics that support human judgement rather than replace it. Strengthening these approaches will enhance early intervention and strengthen the effectiveness and legitimacy of U.S. counterterrorism strategies.

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Source of support: Nil; **Conflict of interest:** Nil.

Cite this article as:
Popoola, J. G. & Aryee, C. "Leveraging Behavioral Analytics to Prevent Lone-Actor Terrorism in the United States: A Scoping Review." *Sarcouncil Journal of Humanities and Cultural Studies* 5.1 (2026): pp 12-18.

Publisher: SARC Publisher