



# A Systematic Review of Systems Science Approaches to Understand and Address Domestic and Gender-Based Violence

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## Abstract

**Purpose** We aimed to synthesize insights from systems science approaches applied to domestic and gender-based violence.

**Methods** We conducted a systematic review of systems science studies (systems thinking, group model-building, agent-based modeling [ABM], system dynamics [SD] modeling, social network analysis [SNA], and network analysis [NA]) applied to domestic or gender-based violence, including victimization, perpetration, prevention, and community responses. We used blinded review to identify papers meeting our inclusion criteria (i.e., peer-reviewed journal article or published book chapter that described a systems science approach to domestic or gender-based violence, broadly defined) and assessed the quality and transparency of each study.

**Results** Our search yielded 1,841 studies, and 74 studies met our inclusion criteria (45 SNA, 12 NA, 8 ABM, and 3 SD). Although research aims varied across study types, the included studies highlighted social network influences on risks for domestic violence, clustering of risk factors and violence experiences, and potential targets for intervention. We assessed the quality of the included studies as moderate, though only a minority adhered to best practices in model development and dissemination, including stakeholder engagement and sharing of model code.

**Conclusions** Systems science approaches for the study of domestic and gender-based violence have shed light on the complex processes that characterize domestic violence and its broader context. Future research in this area should include greater dialogue between different types of systems science approaches, consideration of peer and family influences in the same models, and expanded use of best practices, including continued engagement of community stakeholders.

**Keyword** Systems Science · Agent-Based Modeling · System Dynamics Modeling · Social Network Analysis · Network Analysis · Domestic Violence · Intimate Partner Violence · Gender-Based Violence

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## Introduction

Domestic and gender-based violence, including physical or psychological aggression by a current or former intimate partner, sexual victimization, sex trafficking, and other forms of violence based on socially-ascribed gender norms, affects millions of individuals worldwide, but has remained frustratingly impervious to many prevention efforts (Cooper et al., 2013; Jewkes, 2014; United Nations General Assembly, 1993). There is a critical need for novel approaches that bring together practitioners and researchers from diverse disciplines to address the complex dynamics that govern domestic and gender-based violence in different populations (Jewkes, 2014). Systems science approaches, which aim to identify and explain system-level behavior using a range of conceptual and computational methods implemented by interdisciplinary teams (Mabry et al., 2008), hold potential to shed light on the complex drivers and

consequences of domestic and gender-based violence and optimal strategies for prevention and intervention.

### Domestic and Gender-based Violence are Complex Problems

Domestic and gender-based violence exhibit complex patterns, including unpredictability, varying degrees of reciprocity between partners, dynamic patterns of escalation and de-escalation within relationships, and influences across time, space, and society that may exacerbate but also negate risks (Burge et al., 2016). Social norms accepting of or against domestic and gender-based violence may spread through households and high schools (Banyard et al., 2022; Sandberg et al., 2021), while the reactions of members of one's social network to domestic violence disclosures may influence survivors' ability to access support (Trotter & Allen, 2009). As such, the prevalence and consequences of domestic and gender-based violence in different populations reflect the complex intersection of individual, family, social network, community, societal, and structural factors (Larsen, 2016; Mackenzie et al., 2015).

The mental and physical health consequences of domestic and gender-based violence are also characterized by complex interrelations and multiple causal pathways. For example, associations between intimate partner violence (IPV) and risk for human immunodeficiency virus (HIV) may be due to a direct influence of IPV on HIV risk, shared risk factors for both IPV and HIV risk, or some other mechanism (Rigby & Johnson, 2017). Feedback loops (i.e., bidirectional relations) are also common in domestic and gender-based violence and its consequences, illustrated by alcohol use as a coping mechanism among survivors that may also exacerbate their IPV risk (Katerndahl et al., 2022).

Interventions to prevent domestic and gender-based violence and mitigate its consequences also demonstrate complexity. In particular, domestic violence interventions can be targeted to the individual, interpersonal, or community levels and may have unintended consequences in addition to positive benefits (Koss et al., 2011; Mears & Visher, 2005). For example, reviews of policies and services designed to help domestic violence survivors have identified potential “retaliation” or “backlash” effects of some interventions, which increase rather than decrease homicide risk among survivors (Dugan et al., 2003a, b). This includes differential effects of protection orders, which may anger abusive partners while failing to effectively sever contact between offenders and lower-resourced victims (Dugan et al., 2003b).

### Systems Science Approaches

Systems science approaches aim to examine population-level effects that arise from interrelationships among elements of

a complex system. These approaches embrace *non-linearity* (e.g., responses to the actions of others are not necessarily predictable), *dynamics* (i.e., incorporating elements that change over time), *feedback loops* (i.e., bidirectional relationships that either reinforce or negate each other), *stochasticity* (i.e., elements occur according to probabilities, rather than being deterministically specified), and *emergence* (i.e., system-level effects are greater than the sum of individual properties or behaviors) (Carey et al., 2015; Lich et al., 2013; Winkler et al., 2022). Therefore, these approaches hold potential to shed light on the complex problems of domestic and gender-based violence.

Systems science approaches use a range of conceptual and computational methods (Luke & Stamatakis, 2012; Mabry et al., 2008; Urban et al., 2011). Conceptual systems science methods include systems thinking, which examines interrelationships between parts of a system and their relationships to the system as a whole (Carey et al., 2015; Trochim et al., 2006), and group model-building, which explicitly maps out interrelations through a participatory process with diverse *stakeholders* (i.e., any entities who can affect or are affected by an issue) (Hovmand et al., 2012). Computational systems science approaches include agent-based modeling (ABM), system dynamics (SD) modeling, and network analysis (NA) (Lich et al., 2013; Luke & Stamatakis, 2012).

ABM uses computational modeling to simulate a population, with agents (reflecting individuals, organizations, or other entities of interest) interacting in an artificial environment according to pre-defined rules (Auchincloss & Diez Roux, 2008; Epstein, 1999; Luke & Stamatakis, 2012; Tracy et al., 2018). Agents adapt their behavior over time in response to their interactions with other agents and with their environment, producing population-level patterns that are difficult to predict from individual-level behaviors. ABM has particular strengths for capturing individual heterogeneity, processes of “contagion” through networks that change over time, and multiple levels of influence (Luke & Stamatakis, 2012; Tracy et al., 2018). ABM approaches can be used to explore mechanisms driving population-level patterns, and/or as a virtual laboratory to explore outcomes under different conditions (Auchincloss & Diez Roux, 2008; Epstein, 1999). ABM has been used to compare the relative impacts of different interventions and policy changes on rates of community violence (Goldstick & Jay, 2022) and to identify optimal infection control strategies, including mitigation strategies against COVID-19 infection among elementary-age students attending in-person schools (Morrison et al., 2023).

SD modeling is an aggregate approach that uses differential equations to represent the dynamics of a system, including feedback loops and transitions between homogeneous states (Homer & Hirsch, 2006; Naumann et al., 2019;

Sterman, 2006). One aspect of SD modeling is causal loop diagramming (CLD), in which hypothesized causal relationships are mapped to create a qualitative visualization of the system, often through an iterative process with input from diverse stakeholders (Deutsch et al., 2022; Homer & Hirsch, 2006). In particular, feedback loops, including reinforcing (or positive) loops that maintain behavior over time, and balancing (or negative) loops that undermine or negate behavior over time, are identified (Gear et al., 2018; Lich et al., 2013). In these causal diagrams, components of the system accumulate in “stocks” (representing people, disease states, or other relevant homogeneous entities), with “flows” representing transitions between stocks (Luke & Stamatakis, 2012). These causal diagrams are then translated into computational models to examine system behavior. Similar to ABM, SD modeling can be used to explore causal mechanisms and effects of potential interventions on the system over time, allowing the identification of potential leverage points for maximum population-level impact (Homer & Hirsch, 2006; Lich et al., 2013; Naumann et al., 2019). SD modeling has been used to explore the dynamics governing youth violence in urban areas (Bridgewater et al., 2011) and to inform decision-making about how best to scale up programs to support housing security among families involved in the child welfare system (Fowler et al., 2020).

Social network analysis (SNA) examines relationships between a set of entities, including individuals, community organizations, businesses, or governments, commonly referred to as “actors” (Lich et al., 2013; Luke & Stamatakis, 2012; Valente, 2010; Wasserman & Faust, 1994). In constructing a visualization of the social network, actors in the network are represented as “nodes” (or “vertices”), while the relationships between them are represented as “edges” (or “ties”) (Clifton & Webster, 2017). Social networks can be constructed through collection of data on a whole population within a certain boundary, creating a sociocentric (or whole) network comprised of all ties within that population, or on the egocentric (or personal) networks of a limited number of individuals from a population of interest. In sociocentric studies, rosters or nomination methods may be used to elicit ties between all population members, whereas in egocentric studies, the study participants (“egos”) are asked to list a certain number of their close ties (“alters”) and provide information about their characteristics and relationship. The social network structure can then be analyzed, and associations between characteristics of egos and alters can be evaluated. SNA studies have been used to assess social contagion of behaviors (or “influence” effects, whereby the behavior of network members directly influences one’s own behavior), as well as the role of homophily (or “selection” effects, whereby individuals tend to create ties with others who are similar to them) in promoting the clustering of behaviors within subgroups of the population (Rosenquist et al., 2011).

Researchers have also examined the effects of one’s network position on risk for adverse outcomes (Fulginiti et al., 2016).

Although “network analysis” broadly refers to analyses of relationships, for the purposes of this review, we distinguish between “social network analysis” as focused on relationships between people or organizations, and “network analysis,” as focused on relationships between other kinds of entities, like risk factors and symptoms, that exist within individuals. NA applied to risk factors and symptoms is increasingly used within the psychological sciences to visualize relationships and identify clusters of symptoms, behaviors, and risk factors (Benfer et al., 2018; Bijlsma et al., 2022; Borsboom & Cramer, 2013; Epskamp et al., 2018).

## The Current Study

Past reviews have synthesized findings from systems science applications to health behavior (Yang, 2019), injury and violence (Goldstick & Jay, 2022; Naumann et al., 2019), public health evaluations (McGill et al., 2021), and general public health (Carey et al., 2015). However, to our knowledge, no review has summarized systems science approaches to domestic and gender-based violence, despite a large body of literature on social network influences (e.g., Nolet et al., 2021; Sandberg et al., 2021) and complexity (e.g., Burge et al., 2016) in this field. In this systematic review, we aimed to synthesize research to date that used a systems science approach to study risks, outcomes, interventions, and/or community responses associated with domestic and gender-based violence. We identify the major insights into domestic and gender-based violence that have emerged from the systems science literature and present an informed research agenda for future systems science applications to complement other research aimed at understanding and addressing domestic and gender-based violence.

## Methods

We conducted this systematic review according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). Our inclusion and exclusion criteria, search strategy, review process, data extraction, and quality assessment were specified in advance and documented in a systematic review protocol (Online Resource). For the purposes of this review, we defined “domestic and gender-based violence” broadly, as any physical, sexual, or emotional violence perpetrated by a current or former intimate partner (e.g., intimate partner violence, spousal abuse, dating violence) or on the basis of socially-ascribed gender differences (e.g., violence on the basis of gender nonconformity, gender expression or identity, perceived

sexual orientation) (Breiding et al., 2015; United Nations General Assembly, 1993). In particular, our definition of gender-based violence included sexual violence of all forms and human trafficking (Burke et al., 2020; Cooper et al., 2013).

## Search Strategy

We searched for articles and book chapters indexed in nine inter-disciplinary databases: Book Citation Index: Science, EBSCO: Academic Search Complete, PsycINFO, PubMed, ScienceDirect, Social Sciences Full Text, Sociological Abstracts, SpringerLink, and Web of Science. We included search terms for domestic and gender-based violence (“intimate partner violence” OR “intimate partner abuse” OR “relationship violence” OR “relationship abuse” OR “relationship aggression” OR “spous\* violence” OR “spous\* abuse” OR “spous\* aggression” OR “marital violence” OR “marital abuse” OR “marital aggression” OR “dating violence” OR “dating abuse” OR “dating aggression” OR “partner violence” OR “partner abuse” OR “partner aggression” OR “couple violence” OR “domestic violence” OR “domestic abuse” OR “battered women” OR “battering” OR “wife beating” OR “intimate terrorism” OR “gender-based violence” OR “violence against women” OR “stalk\*” OR “honor-based violence” OR “rape” OR “sexual violence” OR “sex offenses” OR “sexual assault” OR “sexual exploitation” OR “trafficking”) AND systems science (“systems science” OR “systems thinking” OR “complexity science” OR “complex system” OR “systems modeling” OR “group model-building” OR “agent-based model\*” OR “individual-based model\*” OR “system\* dynamic\*” OR “causal loop diagram” OR “network analys\*” OR “social network” OR “computational model”).

To capture any studies we may have missed with our search strategy, we also conducted manual searches for additional articles, including a “backward” reference search of included articles, a “forward” reference search of papers citing included articles, a search of reference lists of key literature reviews (Carey et al., 2015; McGill et al., 2021; Naumann et al., 2019; Nianogo & Arah, 2015), and a search of key journals that publish systems science papers and/or papers on domestic and gender-based violence (see Online Resource).

## Study Selection

We used the following inclusion criteria: (1) peer-reviewed journal article or published book chapter, (2) written/available in English, (3) implemented or developed a systems science approach, including both computational/empirical approaches (e.g., agent-based modeling [ABM], system dynamics modeling [SD], or network analysis [NA]) and

conceptual approaches (e.g., systems mapping, causal loop diagrams, group-model building) and (4) specifically examined some aspect of domestic or gender-based violence. We included published book chapters due to the relative scarcity of published peer-reviewed journal articles applying systems science to domestic violence. However, we did not include conference papers/abstracts, published dissertations/theses, or unpublished work, as these are harder to systematically identify and do not always contain all needed information for data extraction. For computational and empirical systems science approaches, we restricted inclusion to studies utilizing ABM, SD, or SNA/NA as these are the primary systems science approaches used in public health and social science research (Luke & Stamatakis, 2012; Urban et al., 2011). We did not restrict study inclusion based on time, geography, or age of participants because we wanted to include all relevant papers that have applied systems science approaches to domestic and gender-based violence.

Studies were excluded if they did not use a systems science approach or if they did not study domestic violence independent from other forms of family violence or childhood adversity. We also excluded studies that used geographic information systems (GIS) network analysis (e.g., Xia et al., 2020) and semantic network analysis (e.g., Barta, 2021), as these methods were beyond the scope of the current review. Finally, we excluded studies that utilized qualitative data collection on social network members among domestic violence survivors, without constructing or analyzing social networks (e.g., Alaggia et al., 2012).

After removing duplicates from our search results, two independent reviewers (M.T. and L.S.C.) screened studies for inclusion based on their title and abstract. Full-text articles were then reviewed by the same two independent reviewers for inclusion. The reviewers met to discuss and resolve any disagreements to reach consensus.

## Data Extraction, Quality Assessment, and Synthesis

We extracted data from each included study using a standard extraction form. Two authors (M.T. and L.S.C.) each completed data extraction for one-half of the included studies and verified the accuracy of data extraction from the other half. We also evaluated the quality and transparency of each included study, guided by criteria developed by Jalali et al. (2022), which have been used in past reviews of simulation and systems science models (e.g., Cerdá et al., 2022; Winkler et al., 2022). Up to twenty-five criteria assessing model development (e.g., “Does the study involve other stakeholders (e.g., domain experts) in the development?”), testing (e.g., “Does the study calibrate the model to any dataset?”), and analysis (e.g., “Does the paper compare strategies and/or policies using the model?”) were evaluated (see Online Resource for the full list of criteria). Two independent reviewers (M.T. and L.S.C.)

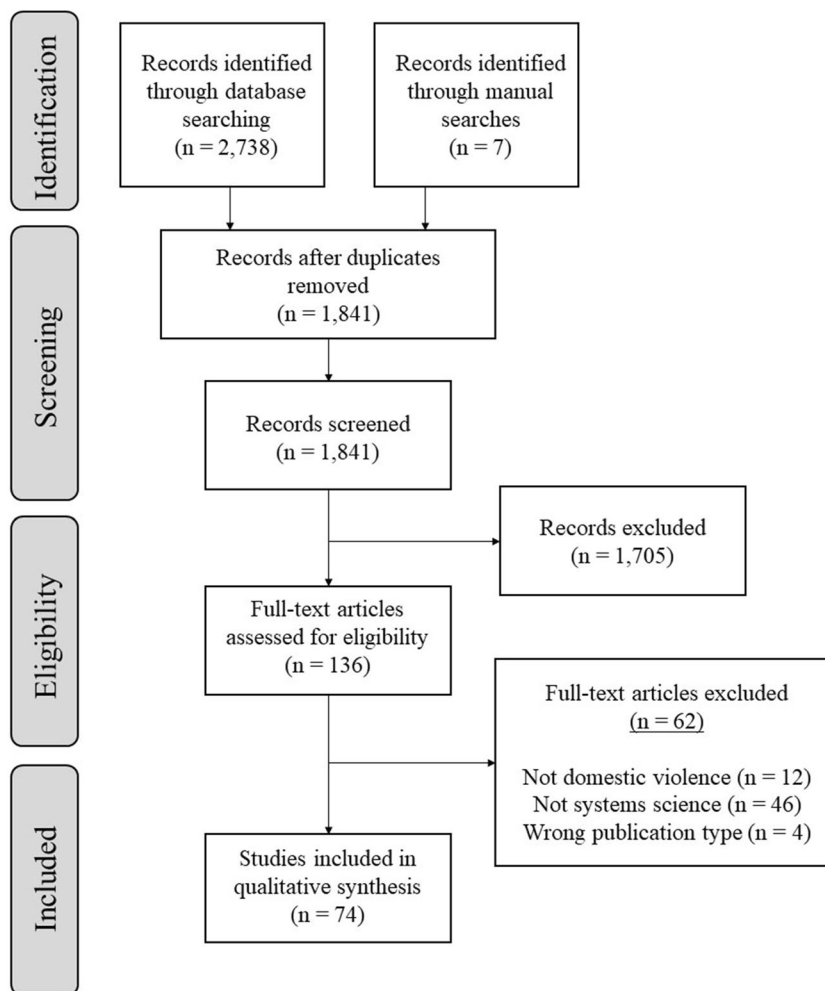
assessed whether each criterion was present, absent, or not applicable for a sample of included studies. Once agreement between reviewers was established, each reviewer evaluated the criteria for one-half of the remaining papers. We judged several criteria focused on simulation modeling (e.g., discussing calibration and model validation) as generally not relevant to SNA and NA studies (see the Systematic Review Protocol in the Online Resource). We divided the number of criteria identified as present (ranging from 0–25 for ABM and SD studies, and 0–15 for SNA and NA studies) by the number of applicable criteria to derive a percentage quality score for each included study.

Given substantial heterogeneity across the included studies in research questions, modeling approach, and effect estimates presented, we used qualitative synthesis to describe the central themes and major findings in the systems science literature on domestic and gender-based violence. We also summarized descriptive information about the included studies using counts and percentages. Studies were grouped by systems science approach for synthesis.

## Results

Our search yielded 2,745 records, with 1,841 records remaining after removing duplicates (Fig. 1). After screening titles and abstracts, we reviewed 136 full-text articles and included 74 studies (six systems thinking studies, eight ABM, three SD, 45 SNA, and 12 NA studies). Characteristics of the included studies are described in Table 1. Most studies ( $n = 35, 47.3\%$ ) focused on IPV or domestic violence victimization and/or perpetration, whereas 20 studies (27.0%) focused specifically on sexual violence victimization and/or perpetration. The majority of studies were conducted in the United States ( $n = 45, 60.8\%$ ) and were targeted to the adult population aged 25 years and older ( $n = 39, 52.7\%$ ), though studies among children (aged < 11 years,  $n = 3$ ), adolescents (aged 11–17 years,  $n = 13$ ), and young adults (aged 18–24 years,  $n = 11$ ) were also included. Non-U.S. studies were primarily conducted in high income countries (e.g., Australia, Canada, England), with a small number conducted in upper-middle income countries (e.g.,

**Fig. 1** PRISMA flow diagram for study selection





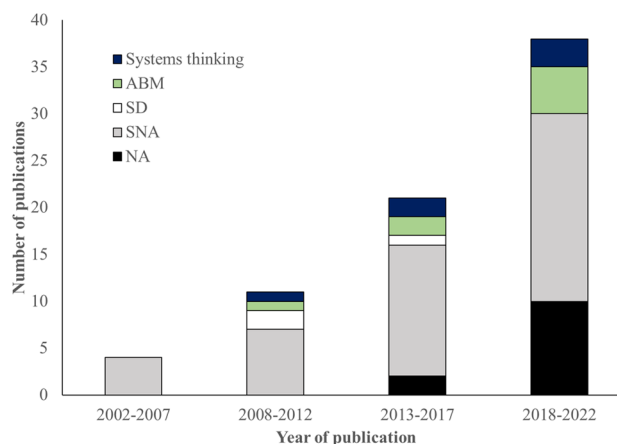
**Table 1** Characteristics of included studies, by study type<sup>a,b</sup>

	Systems thinking	ABM	SD	SNA	NA
Total	6	8	3	45	12
Primary type of violence under study					
IPV/DV victimization or perpetration	3	8	3	16	5
Sexual violence	0	0	0	15	5
Dating violence	0	0	0	2	1
Sex trafficking	0	0	0	5	0
Attitudes towards IPV	0	0	0	5	1
IPV/DV/GBV prevention or services	3	0	0	2	0
Study design					
Cross-sectional	3	0	0	32	9
Longitudinal	3	8	3	13	3
Location					
United States	3	5	3	29	5
Outside of United States	3	2	0	16	7
Unit of analysis					
Individual	n/a	4	1	40	n/a
Couple		4	2	0	
Organization		0	0	5	
Age of target population					
Children (< 11 years old)	n/a	0	0	2	1
Adolescents (11–17 years old)		0	0	12	1
Young adults (18–24 years old)		0	0	7	4
Adults (25 years and older)		8	3	22	6
Gender of target population					
Female	n/a	1	1	15	5
Male		0	0	3	3
Both female and male		7	2	22	4
Complexity features included in study					
Dynamics	n/a	8	3	6	1
Heterogeneity		8	0	45	12
Interactions		8	2	45	12
Multilevel		1	0	11	0
Stochasticity		8	0	0	0
Type of social network					
Egocentric	n/a	n/a	n/a	15	n/a
Sociocentric				30	
Quality assessment of study <sup>c</sup>					
Low	n/a	1	0	13	2
Moderate		4	2	14	4
High		3	1	18	6

<sup>a</sup> Numbers may not sum to total if information on a specific characteristics was not reported in the paper

<sup>b</sup> Abbreviations: *ABM* agent-based modeling; *DV* domestic violence; *GBV* gender-based violence; *IPV* intimate partner violence; *NA* network analysis; *SD* system dynamics; *SNA* social network analysis

<sup>c</sup> Low: met <70% of criteria; Moderate: met 70–80% of criteria; High: met 80–100% of criteria



**Fig. 2** Number of domestic and gender-based violence systems science papers, by publication year and study type<sup>a,b</sup>. <sup>a</sup> Papers “in press” at the time of writing were included in the 2018–2022 category. <sup>b</sup> Abbreviations: *ABM* – agent-based modeling; *NA* – network analysis; *SD* – system dynamics; *SNA* – social network analysis

Brazil, Mexico), and a handful in lower-middle income countries (e.g., Nigeria). An overview of the included studies, assessment of complexity features present in each study, and descriptions of methods and major findings from each study are included in the Online Resource. Our results show that publications applying systems science approaches to domestic- and gender-based violence have been increasing in recent years, with increased ABM, SNA, and NA studies but decreased SD studies over time (Fig. 2). The authors of the included studies were primarily from the disciplines of public health, social work, psychology, criminology, and sociology, with some contributions from urban planning, political science, information and computer sciences, and women and gender studies.

### Systems Thinking Studies ( $n = 6$ )

The goals of the included systems thinking studies were to: (1) illustrate the use of domestic violence-related group model-building in communities (Deutsch et al., 2022; Hovmand et al., 2012); (2) apply a systems approach to evaluating IPV prevention programs (Kearney et al., 2016; Makleff et al., 2020); and (3) interpret qualitative and quantitative data on domestic violence using systems thinking concepts (Caffrey, 2017; Katerndahl et al., 2021a) (Table 2). These studies utilized concepts from systems science to provide insight into varied perceptions, experiences, and inconsistencies related to domestic violence, including women’s decision-making around help-seeking and leaving abusive relationships (Katerndahl et al., 2021a) (Table S3, Online Resource). They also discussed how to engage diverse stakeholders in exploring potential solutions to domestic violence (Deutsch et al., 2022; Hovmand et al., 2012). Importantly,

**Table 2** Representative research aims addressed in included studies, by study type

Study type	Sample research aims
Systems thinking	Use group model building to develop a community prevention strategy for domestic violence among military, veterans, and families affected by trauma (Hovmand et al., 2012) Explore the relevance of complexity science to understanding IPV dynamics and women's decision-making about taking action (Katerndahl et al., 2021a) Apply a complex systems approach to an evaluation of a school-based comprehensive sexuality education intervention with a focus on preventing IPV (Makleff et al., 2020)
Agent-based modeling (ABM)	Improve our understanding of how violent events emerge within couples (Katerndahl et al., 2019) Improve our understanding of the causal pathways between IPV and HIV among women, and evaluate the potential impact of IPV prevention on HIV incidence (Rigby & Johnson, 2017) Evaluate the influence of cultural sensitivity, public awareness, and access to shelters on IPV rates across racial/ethnic and income groups (Drigo et al., 2012)
System dynamics (SD) modeling	Define and understand the structure and behavior of syndemic risk (including IPV) affecting women with and at-risk for HIV in impoverished urban communities (Batchelder et al., 2015) Explain underlying feedback mechanisms driving dynamics around domestic violence victim arrests (Hovmand et al., 2009) Examine how the sequence and timing of three community interventions for domestic violence affect victim safety and offender accountability (Hovmand & Ford, 2009)
Social network analysis (SNA)	Investigate whether IPV acceptance is correlated across socially connected individuals, whether correlations differ by type of relationship, and whether social network position is associated with IPV acceptance (Shakya et al., 2016) Evaluate whether and how network structure affects vulnerability to sexual victimization among adolescent females (Stogner et al., 2014) Examine the relation between violent peers in male adolescents' social networks and IPV perpetration in early adulthood, and the influence of network structure on that relation (Ramirez et al., 2012) Compare the size, structure, and composition of the social networks of women in abusive relationships with those of a matched cohort of non-abused women (Katerndahl et al., 2013) Examine how service providers and community collaborators work together in networks aimed at the primary prevention of sexual violence (Cook-Craig, 2010) Analyze the operations of a major sex trafficking ring between Nigeria and Europe by examining trafficking networks during the recruitment, transportation, and exploitation stages (Campana, 2016)
Network analysis (NA)	Investigate the co-occurrence of individual IPV items, identify the items that are central to each type of IPV, and characterize the interplay between different IPV types (Hacialiefendioğlu et al., 2021) Explore the nature and strength of interrelationships among dynamic risk factors for recidivism among adult male sex offenders (van den Berg et al., 2020) Examine differences in networks of posttraumatic stress symptoms as a function of index trauma type, comparing motor vehicle accidents, sexual assaults, and sudden accidental or violent death of a loved one (Benfer et al., 2018)

Abbreviations: *ABM* agent-based modeling; *IPV* intimate partner violence; *NA* network analysis; *SD* system dynamics; *SNA* social network analysis

they found that exploring feedback loops and collective dynamics using systems thinking enhanced IPV prevention program implementation and evaluation by identifying the specific mechanisms that generated change (Kearney et al., 2016; Makleff et al., 2020).

### Agent-Based Modeling Studies ( $n = 8$ )

The objectives of the included ABM studies were to: (1) explore situational factors that affect violent incidents and help-seeking within relationships (Guidi et al., 2017; Katerndahl et al., 2019, 2020, 2021b, 2022), including in the context of the COVID-19 pandemic (Madeira et al., 2021); (2) examine causal pathways between IPV and HIV risk (Rigby & Johnson, 2017); and (3) evaluate spatial and social influences on disparities in IPV victimization (Drigo et al.,

2012). The series of ABMs by Katerndahl and colleagues (Katerndahl et al., 2019, 2020, 2021b, 2022) built on each other to identify mechanisms (e.g., couple's day-to-day stress, substance use, arguments, and forgiveness) explaining the emergence of violent incidents within couples who had a history of violence, as well as women's decisions to leave the relationship, seek counseling, or take legal action (Table 2; Table S4, Online Resource). Similarly, Guidi et al.'s model (2017) identified patterns of IPV between couples under different conditions of partner aggressiveness, social network IPV, and social support.

Three ABM studies tested their hypotheses by modeling a whole simulated population. Specifically, Madeira et al.'s ABM (2021) found that the impact of social distancing measures during COVID-19 increased domestic violence cases and reduced disclosure of domestic violence.

Drigo et al. (2012) revealed that the largest discrepancies between total and reported number of IPV incidents were among African American women, and that some intervention scenarios actually increased, rather than decreased, IPV among certain population sub-groups defined by race/ethnicity and income. Lastly, Rigby and Johnson's (2017) findings highlighted the explanatory role of higher IPV perpetration among males with concurrent partners in the relations between IPV and HIV in South African heterosexual partnerships.

### System Dynamics Studies ( $n = 3$ )

Unintended consequences and causal pathways were also explored in three SD models of IPV. Specifically, these studies sought to (1) understand IPV's role in syndemic risk among women with and at-risk for HIV in lower income urban communities (Batchelder et al., 2015); (2) explore feedback mechanisms driving increases in arrests of domestic violence victims after implementation of mandatory arrest policies (Hovmand et al., 2009); and (3) identify the optimal sequencing and timing of community-level domestic violence interventions (Hovmand & Ford, 2009) (Table 2; Table S5, Online Resource). Batchelder et al.'s SD model (2015) highlighted women's individual characteristics (e.g., self-worth, perceived financial hardship, drug use, emotional distress) as driving links between IPV experiences and sexual risk behaviors. Hovmand et al. (2009) identified feedback loops, including cooperation and deterrence effects, that influenced dynamic changes in rates of victim arrests after the adoption of a mandatory arrest policy, as well as additional interventions increasing victim advocacy and community coordination of domestic violence responses. Their follow-up model extended this work by varying the sequencing and timing of these three interventions to identify the optimal combination that would maximize offender arrests and minimize victim arrests (Hovmand & Ford, 2009).

### Social Network Analysis Studies ( $n = 45$ )

The included SNA studies generally addressed four types of research aims (Table 2), examining: (1) social network influences on attitudes towards domestic violence (e.g., Shakya et al., 2016); (2) social network influences on risk for IPV victimization and/or IPV perpetration, and how social networks vary by IPV status (e.g., Katerndahl et al., 2013; Ramirez et al., 2012; Stogner et al., 2014); (3) how service providers and community organizations collaborate with each other in networks formed to address domestic violence in communities (e.g., Cook-Craig, 2010); and (4) how sex trafficking networks operate (e.g., Campana, 2016) (Table S6, Online Resource).

Among studies of attitudes towards IPV, four studies found evidence that individual attitudes towards IPV were strongly influenced by IPV acceptance among household members (Shakya et al., 2016, 2018), broader social network members (Sandberg et al., 2021), and peers (Swartout, 2013). However, other studies found only weak or no social network influences on attitudes towards sexual violence among adolescents (Banyard et al., 2022) and when accounting for individual perceptions of network members' attitudes (Itaru, 2003). Two additional studies used SNA to identify youth and adult popular opinion leaders (POLs) to accelerate diffusion of positive attitudes and behaviors as part of a sexual violence prevention program in the U.S., though they reported higher participation by females vs. males (Edwards et al., 2022) and instability in youth identified as POLs over time (Waterman et al., 2022).

Twenty-four SNA studies assessed social network influences on risk for IPV victimization and/or perpetration, as well as reciprocal influences of network structure and IPV risk. Generally, these studies demonstrated associations between peer experiences of IPV and one's own IPV experiences (Foshee et al., 2013; Graham et al., 2014; Mulawa et al., 2016; Patterson et al., 2022; Shakya et al., 2017), with network structure influencing these associations in some cases. For example, in Ramirez et al.'s study (2012), peer violence was most strongly associated with IPV perpetration among males with a larger number of friends.

The included studies consistently highlighted differences in social network structure and composition between individuals with and without a history of IPV. Among adolescents, IPV survivors generally exhibited lower popularity and network centrality compared to non-survivors (Shakya et al., 2017; Tomlinson et al., 2021), though some of these effects were contingent on other aspects of the network like peer deviance (Stogner et al., 2014). Adolescent perpetrators of sexual violence tended to be less integrated in their social networks (Espelage et al., 2022), part of smaller networks with high levels of peer deviance (Casey & Beadnell, 2010), and connected to athletes in high-contact sports (Nickodem et al., 2023). In a longitudinal study by Mumford et al. (2020), adolescents who reported greater closeness and a larger age difference with their friends were at increased risk for dating violence perpetration one year later.

Women with a recent history of IPV reported smaller social networks than women without recent IPV (Coohey, 2007; Katerndahl et al., 2013; Willie et al., 2019), as well as less emotional and practical support (Levendosky et al., 2004). However, IPV survivors often built up their social networks after assault or after leaving the violent relationship (Jaffe et al., 2022; Nolet et al., 2021). Female domestic violence survivors tended to express dissatisfaction with the support received from family members (Fry & Barker, 2002; Roditti et al., 2010), though more in-home network



members decreased risk of adjustment problems among children exposed to domestic violence (Miller et al., 2014). Lack of kin ties and network diversity also increased suicide risk in female refugee IPV survivors (Um et al., 2021).

The gender composition of network members may have important influences on IPV, with some studies finding increased risk for victimization among females with more male friendships (Petering et al., 2014; Stogner et al., 2014) and among college students with fewer same-gender friendships (Patterson et al., 2022). However, more same-gender ties were associated with increased risk of sexual violence perpetration among high school students (Nickodem et al., 2023). IPV survivors frequently disclosed abuse to network members, especially to female network members (Dworkin et al., 2016) and when network members had themselves experienced IPV (Levendosky et al., 2004).

Eight SNA studies examined collaborations aimed at domestic violence prevention and response. Studies at the organizational level highlighted the central role of community mental health centers and domestic violence providers in the coordination of community domestic violence prevention and response (Cook-Craig, 2010; Dsouza et al., 2021). These studies also examined the variety of network structures present in community collaboratives (Cook-Craig, 2010; Greeson et al., 2019) and among European countries participating in gender-based violence prevention (Montoya, 2008), and evaluated the role of concordance between network members on the definition of and response to domestic violence in order to bring about effective systems change (Nowell, 2010). Finally, additional studies noted the central role of the Title IX coordinator and other administrators in a university sexual assault prevention network (Madden et al., 2021); the central role of social workers in facilitating effective responses to IPV in primary care centers (Goicolea et al., 2019); and the primacy of female researchers and faculty clustered at a small number of U.S. universities in producing research on violence against women (Munoz-Munoz & Miron-Valdivieso, 2017).

The final group of SNA studies examined the structure of sex trafficking networks, using records from law enforcement investigations and court cases. Generally, these studies confirmed the central role of “madams” (i.e., women formerly enslaved as prostitutes who participate in trafficking other women) and others involved in the management and control of the trafficking process, while highlighting the overall decentralized nature of the networks, with most actors on the periphery and limited to only one stage in the trafficking process (e.g., recruitment, transportation) (Campana, 2016; Cockbain et al., 2011; Diviak et al., 2021; Mancuso, 2014). Collaboration and co-offending tended to occur within the same stage of trafficking (Campana, 2016) or within smaller subgroups (i.e., cliques) of the larger network (Sabon et al., 2021).

## Network Analysis Studies ( $n = 12$ )

Rather than focusing on interrelations between people (i.e., SNA), publications that utilized a network analysis approach assessed interrelations between variables (Table S7, Online Resource). NA studies used data from population-based surveys, risk assessments completed in clinical and child welfare settings, and emergency department (ED) records, and generally addressed three types of research questions (Table 2): (1) how are different IPV experiences or attitudes towards IPV related to each other? (Hacialiefendioğlu et al., 2021; Rodriguez et al., 2021); (2) how are risk and/or protective factors for IPV incidence and recidivism related to each other? (Baeza et al., 2022; Bijlsma et al., 2022; Leone et al., 2019; van den Berg et al., 2020); and (3) how are mental health symptoms related to each other among IPV survivors or adults with a history of IPV perpetration? (Benfer et al., 2018; Gilbar, 2020; Trupp et al., 2021).

Major findings from NA studies included high levels of co-occurrence between specific experiences of psychological and physical aggression, and the tendency of sexual violence experiences to cluster together but not co-occur with physical or psychological aggression (Hacialiefendioğlu et al., 2021). Several studies also identified strong interrelations between demographic, socioeconomic, family, and community risk factors for both sexual/dating violence and self-harm (Baeza et al., 2022; Costa et al., 2017; Gittins Stone et al., 2017). In addition, domestic violence history emerged as the most central risk factor for child maltreatment (Vial et al., 2020), while impulsivity was central to psychopathy and violent recidivism among adult male sex offenders (Trupp et al., 2021; van den Berg et al., 2020). Gender differences in attitudes towards and risk factors for IPV were also identified (Bijlsma et al., 2022; Rodriguez et al., 2021). NA studies also confirmed constellations of posttraumatic stress disorder (PTSD) and complex PTSD symptoms among young adult female survivors of sexual assault (Benfer et al., 2018) and men in treatment for domestic violence (Gilbar, 2020). Finally, Leone et al. (2019) used ED records to identify specific clusters of diagnoses related to physical, psychological, or sexual IPV among women, including relations between alcohol/substance abuse diagnoses and psychological IPV and between pregnancy-related conditions and sexual and physical IPV.

## Quality Assessment

Overall, the included quantitative studies met about three-quarters of the applicable quality and transparency criteria (mean score = 75.2%). The percent of applicable criteria met was similar across the different study types (74.7% for SD,

74.8% for SNA, 75.6% for NA, and 77.0% for ABM studies). All studies met criteria such as defining the problem addressed by the study, presenting information on parameter values and data sources, evaluating and testing the model (other than calibration), and discussing structural insights regarding what parts of the model may influence the results (Fig. S1, Online Resource). Among SNA and NA studies, criteria that were least commonly present included stakeholder engagement (31.6%), presenting potential conflicts of interest (52.6%), and providing enough information about modeling assumptions (54.4%) (Fig. S2, Online Resource). Almost all SNA and NA studies (96.5%) presented the modeling objective and quantitative results. In contrast, among ABM and SD studies, only 45% presented quantitative results and discussed how to replicate the model, 27.3% presented modeling code and included stakeholder engagement, and 18.2% reported results from sensitivity analyses. However, all ABM and SD studies reported the software used, compared the model results to other studies, and discussed the generalizability of results (Fig. S3, Online Resource).

## Discussion

Our systematic review revealed that the number of systems science applications to understand and address domestic and gender-based violence has increased substantially in recent years. The inter-disciplinary nature of many of the research teams behind this work, including collaborations between psychology, sociology, social work, public health, and criminology researchers and practitioners, was critical to the diversity of angles from which domestic and gender-based violence was assessed in these papers. However, almost all of the included studies were conducted in the U.S. or other higher-income countries, and some important aspects of domestic and gender-based violence, including emotional and economic abuse, were under-represented.

### Strengths and Major Findings of Systems Science Approaches Applied to Domestic and Gender-based Violence

The studies included in this systematic review illustrate the major methodological strengths of systems science approaches for understanding and addressing domestic and gender-based violence. First, these approaches explicitly model the interactions between people for a broader understanding of risks for domestic violence occurrence and resources for domestic violence survivors. Second, these approaches account for multiple levels of influence (e.g., from family members, peers, and communities) and their dynamics over time, including over the course of an abusive relationship. Third, computational systems science

approaches can accommodate and triangulate data from a variety of sources in a way that would be impossible in traditional models and that circumvents some of the limitations of relying on single data sources, in which domestic violence may be under-reported. Fourth, the generative nature of these approaches, compared to traditional statistical models, provides insight into the mechanisms that increase risk for domestic violence and adverse outcomes among domestic violence victims in different contexts. The patterns of findings that emerge from these approaches can be used to understand the development of norms and changes at the population level, including net and unexpected effects of interventions and policies aimed at addressing attitudes towards and experiences of domestic and gender-based violence.

Overall, the systems science studies we reviewed were well-positioned to explore unexpected effects of policies aimed at IPV prevention, including reduced safety among domestic violence survivors after adoption of mandatory arrest policies (Hovmand et al., 2009) and increased, rather than decreased, IPV rates among women in response to increased cultural sensitivity, public awareness, and access to domestic violence shelters (Drigo et al., 2012). Other unexpected findings included an increased longitudinal risk for dating violence perpetration associated with having closer friendships during adolescence (Mumford et al., 2020). Understanding both the situational factors driving domestic violence incidents (e.g., Graham et al., 2014; Katerndahl et al. In press) and larger social and structural influences on IPV risk (Baeza et al., 2022; Drigo et al., 2012) are important to identify potential negative effects of IPV interventions and explain unexpected effects.

The findings from most SNA studies highlighted the tendency of IPV to cluster within networks (e.g., due to homophily in friendship formation, either based on similar IPV histories or similar risk factors) and the direct influence of network members on IPV-related attitudes and behaviors. This is similar to evidence of network influences on other behaviors, both negative (e.g., adolescent delinquency and drinking) (McMillan et al., 2018) and positive (e.g., increased physical activity among adults) (Prochnow & Patterson, 2022). Importantly, differential network effects may be at play for different types of network members (e.g., stronger associations between individual and household member IPV acceptance among women) (Shakya et al., 2016).

In addition, the included SNA studies highlighted the potential for SNA to inform social network interventions aimed at IPV prevention by identifying individuals on the periphery of the network who may promote negative attitudes (Shakya et al., 2016) or popular opinion leaders (POLs) who could diffuse positive attitudes and behaviors (Edwards et al., 2022; Makleff et al., 2020), as well

as disrupt sex trafficking networks (Cockbain et al., 2011) and enhance collaboration among community stakeholders (Nowell, 2010). Interventions based on diffusion of norms have been successful for other public health programs, including suicide prevention (Wyman et al., 2010), though challenges may include smaller networks among individuals at risk for IPV (Jaffe et al., 2022), frequent fluctuations in peer groups and POLs during adolescence (Banyard et al., 2022; Waterman et al., 2022), and frequent turnover in community collaborations (Nowell, 2010).

### Areas where Systems Science Applications to Domestic and Gender-based Violence could be Strengthened

Despite the insights made possible by the methodological strengths of systems science studies, these approaches are still constrained by the conceptual models and available data used in their development, as well as in the extent to which applications take full advantage of these methodological strengths. Regarding the inclusion of different aspects of domestic and gender-based violence in existing systems science studies, most of the included studies focused on IPV or domestic violence generally (i.e., encompassing all kinds of psychological, physical, and sexual aggression), while smaller subsets specifically studied physical violence (e.g., Coohy, 2007; Petering et al., 2014; Ramirez et al., 2012), sexual violence (e.g., Graham et al., 2014; Jaffe et al., 2022; Stogner et al., 2014), and sex trafficking (e.g., Campana, 2016; Cockbain et al., 2011; Sabon et al., 2021). A few studies examined interrelations between and correlates of different types of IPV and specific IPV experiences (Baeza et al., 2022; Hacıaliefendioğlu et al., 2021; Leone et al., 2019), highlighting the strong co-occurrence of different types of IPV (except sexual violence) (Hacıaliefendioğlu et al., 2021) and the escalation of violence severity and frequency within relationships (Guidi et al., 2017; Katerndahl et al., 2019, 2022). Although psychological aggression is a potential precursor to physical violence (Salis et al., 2014; Shortt et al., 2012), only three of the included studies examined emotional victimization separately (Hacıaliefendioğlu et al., 2021; Leone et al., 2019; Patterson et al., 2022). Although it's difficult to disentangle IPV behaviors and experiences, focusing on emotional aggression may be an important target for IPV prevention, particularly among adolescents, whose views on relationship practices are still mutable and subject to peer influences (Banyard et al., 2022; Edwards et al., 2022). Furthermore, none of the included studies specifically examined economic abuse or coercion, which is a critical but sometimes “invisible” component of IPV that affects survivors' independence (Postmus et al., 2012). In addition, only five studies examined sexual harassment (Baeza et al., 2022; Costa et al., 2017; Espelage et al., 2022; Itaru, 2003;

Nickodem et al., 2023), which is a common form of gender-based violence. The vast majority of systems science studies of domestic and gender-based violence were conducted in the United States and other high-income countries. The studies that were conducted outside of the U.S. primarily used a public health lens, and shed light on attitudes towards IPV in different populations and on human trafficking networks, but did not address the full range of domestic and gender-based violence concerns in these contexts.

Furthermore, most of the SNA studies in this review focused on peer influences among adolescents (e.g., Casey & Beadnell, 2010; Espelage et al., 2022; Stogner et al., 2014). Despite the primacy of peers in adolescence, individuals continue to be shaped by childhood exposures as they age into young adulthood, including strong influences of childhood exposure to IPV on their own future risk for IPV victimization and perpetration (Wood & Sommers, 2011). A few studies accounted for childhood violence exposures or other family-level factors as control variables in SNA analyses, but did not study the relative or moderating influence of these factors, or consider the larger impacts of historical and intergenerational trauma, though community stakeholders identified these as critical for domestic violence (Deutsch et al., 2022). In addition, the gender composition of one's social network may be important for both IPV risk and disclosure of IPV (Nickodem et al., 2023; Patterson et al., 2022; Petering et al., 2014; Stogner et al., 2014), but findings were inconsistent across studies, as has been reported for adolescent drinking (Deutsch et al., 2014), and were limited by restriction to single-gender networks in some studies (e.g., Graham et al., 2014; Tomlinson et al., 2021).

Regarding the optimal use of these approaches, although ABM and SD studies have the potential to incorporate insights from SNA and NA studies when defining the nature of interactions between agents (in ABMs) and developing causal loop diagrams (in SD models), existing ABM and SD studies of domestic and gender-based violence have not yet incorporated insights from SNA or NA. Although multiple ABMs included some aspect of social network influence (e.g., disclosing abuse to friends in Drigo et al.'s (2012) model, violence among other couples in the community influencing IPV risk in Guidi et al.'s (2017) model), more complex and dynamic influences of social network position and composition on IPV risk and help-seeking behavior were not incorporated. Similarly, the small number of existing SD models of domestic violence focused either on aggregate community-level patterns (Hovmand et al., 2009; Hovmand & Ford, 2009) or a constrained set of individual-level risk factors (Batchelder et al., 2015) and could be enhanced by incorporating interrelationships that have been identified in NA studies. Results of ABM and SD studies could, in turn, be used to develop new hypotheses about the role of social networks and causal relationships in IPV and explored in

future SNA and NA studies. Notably, the NA studies were all published after the included SD studies, as the types of systems science approaches being applied to domestic and gender-based violence shifted, creating new opportunities for insights as this literature continues to evolve.

We rated the included studies as having moderate quality and transparency, with 75% of applicable criteria met, on average. The criteria that were most and least consistently met were similar to those identified in other recent quality assessments of systems science and simulation models of the opioid crisis (Cerdá et al., 2022) and the retail food environment (Winkler et al., 2022). Only one of the included ABM studies utilized a standard framework (e.g., the Overview, Design Concepts, and Details [ODD] protocol) (Grimm et al., 2006) for describing the model (Drigo et al., 2012). Furthermore, less than half of the ABM and SD studies reported quantitative results, instead presenting figures illustrating trajectories or patterns of outcomes across different model scenarios (Guidi et al., 2017; Hovmand & Ford, 2009; Katerndahl et al., 2019), which were difficult to fully interpret. Few ABM and SD studies shared information on how to replicate the model or provided model code. Stakeholder engagement, though a central focus of the group model-building process discussed in some of the included studies (Deutsch et al., 2022; Hovmand et al., 2012), was rarely described.

## Future Research Directions

We recommend three primary future research directions to enhance our ability to understand and address domestic and gender-based violence. First, we call for greater dialogue between systems science applications to domestic violence, including using specific insights from SNA and NA studies in the development of causal diagrams for SD models and behavioral rules governing interactions in ABMs. Hybrid modeling approaches, in which multiple systems science methods are used in tandem (Cassidy et al., 2019), may also provide unique insights into domestic violence etiology and response, and should be explored. Systems thinking approaches also represent opportunities to incorporate qualitative data in computational models (Yang, 2019), and insights from gender and intersectionality theory (Jewkes, 2014), which are important to fully characterize interrelationships relevant for domestic and gender-based violence and inform interventions. Second, we encourage systems science modelers to evaluate the joint effects of a broader range of risk factors across the life course, including simultaneously considering both family and peer influences on IPV attitudes and behaviors emerging in adolescence and young adulthood. Systems science approaches are well-suited to incorporating multiple levels of influence and assessing net effects of joint influences that may act in opposition to or exacerbate each other, providing a unique opportunity for

greater insight into causal pathways and targets for intervention. Third, we suggest the expanded application of best practices in model development and dissemination in the systems science domestic and gender-based violence literature. Participatory group model building already has a strong history of use in systems science applications to both community and domestic violence (Bridgewater et al., 2011; Deutsch et al., 2022; Frerichs et al., 2016; Hovmand et al., 2012), and continued stakeholder engagement is critical to advancing our understanding of forces affecting domestic and gender-based violence and opportunities for prevention. More consistent descriptions of computational models of domestic and gender-based violence using existing frameworks (e.g., using the ODD protocol for ABM studies) (Grimm et al., 2006) and making code publicly available will ensure that diverse groups of researchers can expand on each other's work. These efforts will extend the existing literature to shed further light on the complex, non-linear, and dynamic processes that characterize domestic violence and its consequences across the life course and the optimal targeting and timing of intervention strategies.

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## Declarations

**Conflicts of Interest** Nothing to disclose.

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