

Article

Contingencies of Violent Radicalization: The Terror Contagion Simulation

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Abstract: This paper builds confidence in the terror contagion hypothesis that violent radicalization leading to predatory mass violence operates as a system. Within this system, the contingent values of key root causes create channels within which violent ideologies and terrorism emerge. We built a system dynamics simulation model capable of replicating historical reference modes and sophisticated enough to test the contingent values of these propositions. Of 16 propositions, we identified six root-cause propositions that must simultaneously exist, act in concert and explain the dynamics of their interaction which generate a terror contagion. Other propositions can strengthen or weaken an existing contagion but not eliminate it. We use an experiment to demonstrate how changing the contingent values of these propositions creates downward channels. This experiment helps reconcile the swarm vs. fishermen debate over the true root causes of violent radicalization. Within these channels, the contingent values can favor swarm or fishermen manifestations. The simulation and experimentation results enable the future development of the terror contagion hypothesis, provide a testing environment for research on violent radicalization, and provide a pathway to policy development in the combating of terrorism that arises from violent radicalization.



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1. Introduction

In 1995 two perpetrators planned to use improvised explosives to kill their classmates at Columbine High School. When the explosives failed to detonate, the perpetrators improvised a mass-shooting attack which killed 13 people and wounded 24. A wave of media coverage generated by the fatalities broadcast the improvised, rather than intended method as well as a misleading profile of the two perpetrators [1], p. 6. Since 1995, at least 30 perpetrators, some born after Columbine, have seen themselves in that media-constructed representation, and have replicated the improvised mass-shooting method, rather than the intended explosives method, to attack their own schools [2], pp. 6–7. As a seed event, Columbine defined and transmitted a violent ideology and a template method for mass-violence terrorism. In Norway, in 2011, a violent ideology of xenophobia and white supremacy broadened the mass-shooting approach across multiple locations. Among the replications of Norway include the 2019 Christchurch, New Zealand attack. Moreover, even if the claimed contact between the two perpetrators was fabricated, the operational influence on the template method is clear [3], pp. 17–18. The seed event for so-called incels, the Isla Vista attacks of 2014, broadcast a violent ideology of misogyny and a belief in ‘involuntary celibacy’ [4], combined with a template of mass violence through vehicular ramming and mass shooting. In 2017, a wave of ISIS terrorist acts combined the violent ideology of Salafi takfirism with a mixed method of vehicular ramming and knife attacks. In June of 2017, the vehicular ramming template method crossed from one violent ideology to another when a British ultranationalist used it in a copycat retaliation

against Finsbury Mosque attendees [5]. Two months later, in August 2017, a US right-wing extremist used vehicular ramming against Charlottesville protesters in a heavily publicized incident, completing the transition of a method of attack that originated in one violent ideology to another, where it has continued to be used [6].

Historically, the root cause of violent radicalization leading to terrorism such as these incidents has been the subject of debate, with opinion divided between two dominant theories. First is the swarm theory, which proposes that individuals are self-radicalized in loose social networks. Second is the fishermen theory, which proposes that non-state-actor terror networks operating from safe havens lead to violent radicalization, resulting in terrorism [7].

This article advances an alternative to the swarm and fishermen theories: the terror contagion hypothesis. In this hypothesis, violent radicalization operates in a system of social contagion where violent ideology and a template method to conduct terrorism transmits through cultural scripts created by each completed terrorist act. Swarm and fishermen radicalizations in this hypothesis are not the cause of the system but a byproduct of it, representing just two of many potential manifestations arising from the contingent values of the terror contagion system in a given channel within that system.

Our previous work examined the swarm versus fishermen debate through a data set of 4600 terror incidents [8], categorizing profiles by violent ideology and radicalization method. Statistical analysis did not reveal swarm or fishermen categorizations as being more useful for understanding terrorism within these profiles than other factors [9]. Additionally, a previously unidentified third potential radicalization mechanic suggested a deeper system structure, in which these radicalization mechanics are emergent properties of the system rather than causes.

We next proposed such a system by leveraging expert theories of radicalization and linking them into feedback structures [10]. Causal analysis techniques identified numerous potential root causes operating throughout this system. Moreover, the analysis suggested that violent radicalization is a social contagion that is spread by combining a violent ideology with a template method to conduct mass violence. Under certain conditions, furthermore, a contagion can become self-perpetuating, as described in historical cases above.

The main contribution of this paper is to further develop the terror contagion hypothesis through simulation. Our experiments identify which propositions of the terror contagion hypothesis represent the root cause of violent radicalization and under what range of contingencies these propositions operate. We demonstrate that certain values of these contingencies can create channeling effects that favor either swarm or fisherman manifestations, suggesting a source and resolution to the historical debate. Our findings provide a basis for further research in the terror contagion hypothesis.

2. Literature Review

Terrorism has many definitions; however, we stay within the academic consensus [11] by leveraging the Global Terrorism Database (GTD)'s definition of terrorism as "the threatened or actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation" [8], pp. 10–11. The GTD's inclusion criteria require an intentional incident involving violence or the threat of violence against people or property, and perpetrators must not be state actors. The GTD looks for evidence in two of the following three additional categories: First, the action must have occurred outside "legitimate warfare activities." Second, the act must advance political, religious, social, economic, or other widespread change. Third, there must be evidence of "an intention to coerce, intimidate, or convey some other message to a larger audience (or audiences) than the victims" [8], pp. 10–11.

2.1. Theories on Radicalization

Research into violent radicalization leading to terrorism tries to answer the following two questions: who is susceptible, and how does violent radicalization proceed?

Both the IVEE Theory of Radicalization [12] and TRAP-18 [13] approach the susceptibility of an at-risk population without focusing on any specific method of radicalization (see below) or specific violent ideology. Between these two, TRAP-18 indicators appear most robust across populations, including Islamic terrorists, extreme right-wing terrorists, and single-issue terrorists [14], p. 6, such as school shooters.

The second question of how violent radicalization occurs has been dubbed the swarm versus fishermen debate, which is a debate over “root causes” [4], p. 7564. The debate began between two experts in combating terrorism, namely, Hoffman, in 2006 [15,16], and Sageman, in 2008 [7,17]. The theory of swarm radicalization, advocated by Sageman, is “bottom-up”, occurring “in small social groups or ‘bunches of guys’ inspired by and socializing each other...through internal group dynamics” [18], p. 187. This ‘leaderless jihad’ acts like a free market, reacting and adjusting to local domestic conditions without top-down organization and enabling the swarm to appear intelligent and organized as an emergent byproduct of self-organizing and self-directing individuals [17], pp. 144–145.

The theory of fishermen radicalization, advocated by Hoffman, is facilitated by non-state actor organizations that identify, recruit, and radicalize individuals [5], p. 195. An individual does not have to join the non-state actor group to qualify as a case of fishermen radicalization, but the interaction should be meaningful.

Most theories of violent radicalization fall within one of these two camps because the debate represents a classic sociological divide “between structure and agency or the importance of organizations as opposed to individual socializations” [18], p. 179.

During the global war on terror, advocates of swarm or fishermen theories advanced their position through the case-analysis of terrorist incidents associated, even if not directly linked, with Islamic terror networks such as al-Qaeda [19–24]. This over-weighting of the analysis on a single violent ideology of an at-risk population is important to understanding the origins and the contentiousness of the swarm versus fishermen debate, as we describe later in our channeling experiment.

2.2. Theories on Cultural Script Social Contagions: The Werther Effect

If susceptibility concerns “who”, and the radicalization process concerns “how”, cultural scripts answer the question of “what” is conveyed within this process. Cultural scripts are an abstracted, symbolic, meta-language, conveying “cultural norms, values and practices in terms which are clear, precise, and accessible to cultural insiders...” [25], p. 153. The spread of cultural scripts is well known to further social contagions of self-harm in suicide [26,27], as well as affective and predatory violence [28–30]. Suicide contagions, sometimes called Werther contagions, consist of three mechanics. First, the cultural script is broadcast in a *one-to-many* way, resulting in broad distribution across the population [31]. This is accomplished by media reporting on a celebrity’s suicide. Second, the general population receiving the script is filtered by *similarity bias* to those who see themselves in the script’s originator or content [32]. Third, the subset population is narrowed a second time by *prestige bias*. These individuals view the script originator as having high status, celebrity, or in the case of violent behavior, notoriety [33], pp. 558–560. There are several decades of research on how media reporting of celebrity suicides can either increase (Werther effect) or decrease (Papageno effect) the risk of copycat suicides [34], p. 12.

2.3. Simulation Models of Radicalization or Social Contagion

Simulations often model contagions through state transition models (STM), where individuals move between multiple states. In one common class of simulations, these states are linked to the progress of the spread of a disease, and individuals shift between Susceptible Infected and Recovered (SIR) [35], pp. 300–321. The IVEE Theory of Radicalization Simulation exemplifies a SIR approach [12], p. 3. In response to radicalizing content, susceptible individuals transition from non-radicalized to radicalized, becoming “infected” in the SIR framework [12], pp. 7–8. State transition changes in this model are determined by Markov chain stochastic processes based on probabilities [12], p. 2, which

are determined by fitting parameters so that outcomes match known behaviors [12], p. 2. This represents the common challenge of using SIR frameworks with social contagions: the spread of viruses is empirically well understood while cultural scripts are not.

Alternative approaches have been more successful in capturing explicit causal mechanics. An agent-based model (ABM) simulation of the Werther effect successfully demonstrated contagion spread mechanics, including the one-to-many broadcast, self-similarity, and prestige bias effects [31]. Simulations have also depicted a contagion as a complex system [36]. Pruyt et al. demonstrated a technique for exploring deep uncertainty and dynamic complexity using radicalization as their topic, generating thousands of simulations [37] from a common suite. Auping et al. built upon that work by incorporating elements of grievance and the frustration of citizens [38]. The Farmers-Soldiers-Bandits (FSB) model by Saeed et al. is another STM where the states represent group identities, and the movement of individuals between group identities is made explicit. Whether a farmer shifts states to become a soldier or bandit is based on personal factors, incentives, and how individuals perceive their current group identity strength relative to other group identity strengths [39].

2.4. Selection of Simulation Method

We selected system dynamics to simulate the terror contagion hypothesis. System dynamics is well suited for military standards [40], p. 130, simulating complex environments by incorporating diplomatic, informational, military, and economic actions (DIME) and political, military, economic, societal, informational, and infrastructure system interactions (PMESII) [41], pp. 5–10. The system dynamics method also helps achieve DIME-PMESII capabilities for a simulation in order to analyze, understand, forecast, and respond to both adversary and societal behavior [40], pp. 34–44.

Meadows describes a model for understanding as useful in exploring new social problems where “old theories and old social structures are called into question [42], p. 24”, which describes the context of our work well. System dynamics supports developing models for understanding by making the hypothesis and assumptions explicitly clear in structure [43]. Additionally, within an endogenous system, such explicit structure aids in back-tracing behavior to its cause [44]. System dynamics also allows a model for understanding to be extended by operationalizing insights in order to develop pragmatic policies [45], a goal of our long-term work.

Our simulation is a state transition model (STM) and select the FSB over the SIR core representation of those states to build from. Although we use the analogy of a virus for the terror contagion hypothesis, all analogies have limits. SIR populations can only move one way along state transitions, from susceptible to infected and then recovered. In the FSB framework, individuals move fluidly back and forth between states based on the relative power of group identities, network effects, and individually experienced factors. The ability of an individual to self-radicalize themselves is, furthermore, an important feature of the swarm theory. In the disease-influenced SIR approach model, a person can neither will themselves into an infection nor become uninfected simply by exposure and interaction with uninfected people; however, these are characteristics of violent radicalization.

Additionally, in SIR, all infected individuals share the same general ability to infect others by exposure in equal measure. However, not all terrorists are created equal. Many are stopped or ineffective in completing attacks, while a handful generate catastrophic consequences.

3. Terror Contagion Hypothesis

We summarize our prior research beginning with the causal-loop diagram (CLD) system structure, synthesized from expert theories on violent radicalization in Figure 1 [10].

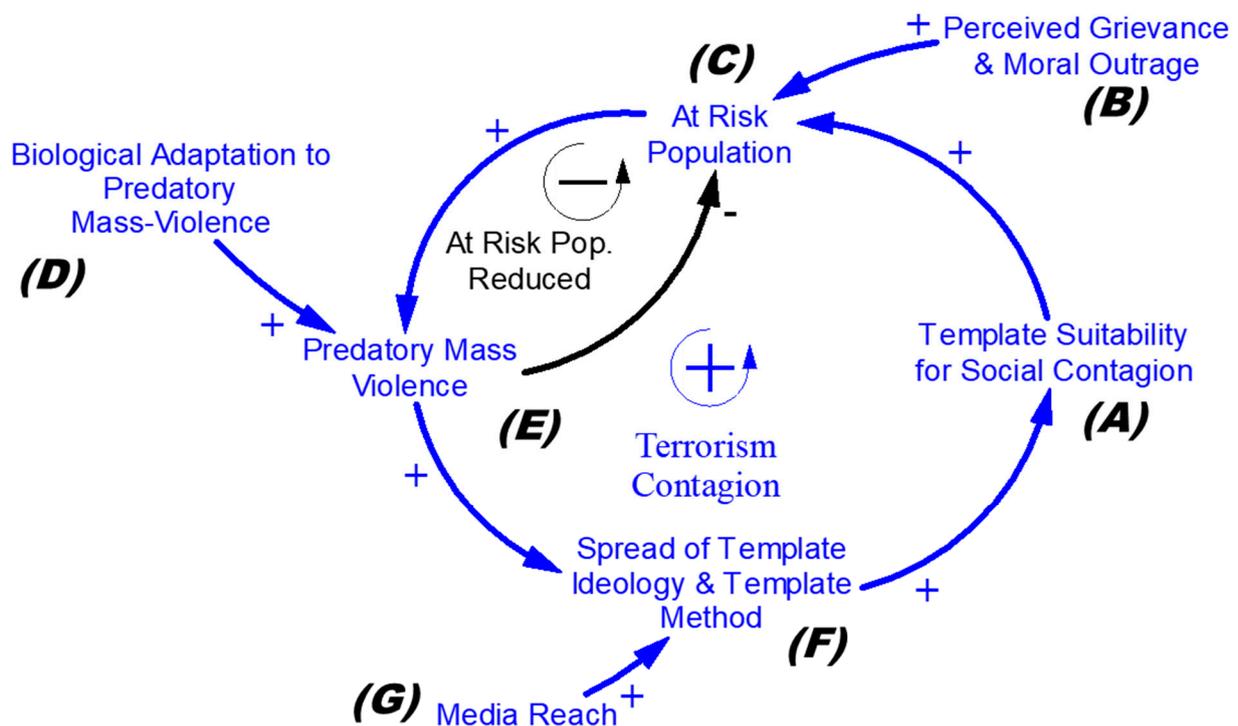


Figure 2. Dynamic hypothesis of the growth of a terror contagion. (A–G) root cause propositions.)

A terror contagion is a form of social contagion spread through cultural scripts by incidents of mass violence. These cultural scripts convey a template ideology and a template method that is suitable for contagion (Figure 2A) based on specific grievances & moral outrage (Figure 2B) within a given at-risk population (Figure 2C). These templates must be suitable in terms of *self-similarity* and *notoriety* in relation to the at-risk population; self-similarity in that they recognize themselves in the perpetrator’s identity, and notoriety in that they view mass violence as a source of celebrity rather than repulsion. The template ideology conveys a conspiracy narrative that explains the perceived grievance, identifies an out-group as responsible, and advocates violence to address it. The template method conveys instructions on how to conduct mass-violence terrorism. These templates operate in concert to activate a biological adaptation to predatory mass violence (Figure 2D), leading to the next mass-violent incident (Figure 2E). This incident results in the spread of template ideology & method (Figure 2F) due to the broad reach of media reporting (Figure 2G). In celebrity suicide Werther contagions, the effect is short-lived because media attention is driven by the celebrity nature of the individual who commits suicide. In a terror contagion, however, media attention is generated by the template method to produce mass fatalities. This means terror contagions can become self-perpetuating. Each subsequently completed act of mass violence furthers the replication and spread of cultural scripts sustaining the contagion of violent radicalization in the at-risk population.

In this paper, we test the 16 propositions listed in Table 1. These quantitative experiments bolster previous qualitative analysis on the six core propositions and allow the numerical comparison and visual inspection of results.

Table 1. Table of Propositions.

ID	Partial Cause	Testable Proposition
1	Template Attractiveness for Social Contagion	Template ideology and method behind terror contagion must be well-cohered, and convey self-similarity and notoriety biases to the at-risk population.
2	Perceived Grievance & moral Outrage	An exploitable grievance exists within or is perceived by the at-risk population.
3	Template Ideology	Cultural scripts must sufficiently convey a conspiracy narrative to an at-risk population.
4	Template Method	Cultural scripts must sufficiently convey the modus operandi of both a pathway to violence and the conducting of the incident.
5	Biological Adaptation to Predatory Mass Violence	Enough of the at-risk population possess the evolutionary adapted trait to predatory violence suited for generating mass violence.
6	Media Reach	Sufficient mass-media or algorithmic social media conveys cultural scripts to at-risk populations through a one-to-many broadcast effect after an incident.
7	at-risk Population	The at-risk population is sufficiently large enough to support the terror contagion.
8	Non-State Actor in the Ungoverned Space	Sufficient violent non-state actors exploit the ungoverned safe haven space to send broadcast and narrowcast cultural scripts of the template ideology & method into governed space
9	Moderating Alternatives	There aren't enough viable alternatives for addressing the grievance within the networks of the at-risk population to dampen radicalization.
10	Abandonment Rate	Abandonment pressure isn't high enough within the networks of the at-risk population to dampen radicalization.
11	Activation Rate	Within the at-risk population, there must be sufficient activation from radicalized to activated in those who seek to begin the pathway to violence.
12	The ratio of radicalized to non-radicalized in an at-risk population.	The ratio between radicalized and-non-radicalized groups of at-risk populations must be sufficient to enable radicalizing effects.
13	Time to Complete Pathway to Violence	The time delay between activation and incident initiation must be long enough to enable sufficient incident success rates, but not so long as to cause forgetting within the at-risk population.
14	Template Method Pathway to Violence Success Rate	Template Method preparation activities must enable sufficient incidents to be initiated without being thwarted.
15	Template Method OTD Success Rates	Template Method must enable sufficient initiated incidents to be completed without being stopped.
16	Template Fatality Rates	Template Method must generate enough fatalities as a result of completed incidents to attract media attention.

4. Reference Modes of a Terror Contagion

Our previous analysis of ~4600 terrorist incidents identified several historical time series of incident frequency by violent ideology, as depicted in Figure 3 [9]. These include completed and uncompleted attempts, measured in per-capita of 1M population and classified by violent ideology. We use these historical time series as the basis for understanding the potential growth and decline of terror contagions.

We identify four behaviors of growth and decline in terrorism attempts within this data. Two of these represent little or no growth. First, Failure to Grow (F2G) is observed where, despite individual terrorist incidents, there is no clear growth, such as in Right-Wing Incidents in Western Europe 1995–2012 (Figure 3G) or Unknown Incidents in both Western Europe and the US between 1995–2014 (Figure 3E.) Next, the Struggle to Grow (S2G) behavior demonstrates mild growth and a long plateau or gradual decline, as seen in Anti-Government incidents in the US (Figure 3I).

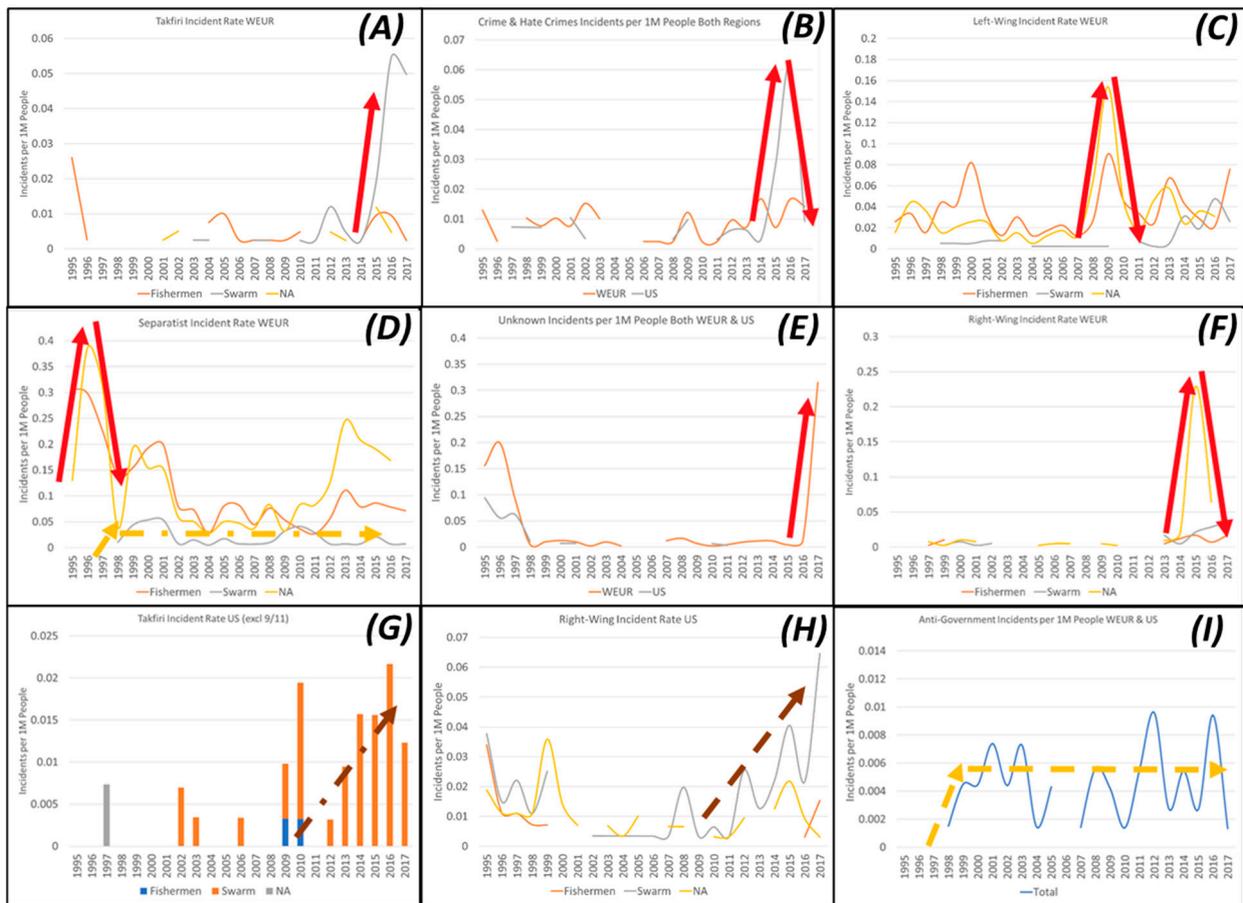


Figure 3. Growth reference modes for (A) Takfiri WEUR, (B) Crimes & Hate Crimes Both Regions, (C) Left-Wing Incidents WEUR, (D) Separatists WEUR, (E) Unknown Both Regions, (F) Right-Wing WEUR, (G) Takfiri US, (H) Right-Wing US, (I) Anti-Government US. Note that Y-axis scales are varied for clarity.

In contrast, the third growth behavior, Contagion (CONT), shows a steady accumulation and a growth in terrorist incidents. This is seen in both Right-Wing Extremism and Salafi Takfiri in the US from 2010 onwards (Figure 3G,H). Finally, Strong Contagion (CONT+) behavior shows very sharp growth over short periods. Strong contagion behaviors are historically seen across various violent ideologies in the US and WUER, including Takfiri 2014-onwards, (Figure 3A); Crime & Hate Crime in the US 2013–2017 (Figure 3B); Left-Wing extremism in Western Europe 2007–2011 (Figure 3C); Separatism in Western Europe 1995–1998 (Figure 3D); and Right-Wing extremism in Western Europe 2013–2017 (Figure 3F).

Shifting from historical time series to reference modes, we abstract these four growth patterns (F2G), (S2G), (CONT), (CONT+) and add three more behaviors in Figure 4 [47], which are Equilibrium (EQ), Hoped, and Feared.

Each reference mode begins in an Equilibrium state in the historical (left side) portion of the chart, where violence may be occurring but is indistinguishable from normal criminal patterns. We locate an abstracted seed event as the vertical line indicating when the terror contagion starts. From that event, growth proceeds along one of several reference modes. A continuation at or close to EQ is an F2G represented by a string of dots. Observable growth patterns in S2G, CONT, and CONT+ are represented by a string of dashes, a combination of dots and dashes, and solid red lines. Although CONT and CONT+ share similar shapes, the sharper rise of a CONT+ relative to a CONT indicates how a strong contagion accelerates radicalization and is more severe in its behavior. Hoped and Feared, depicted by gray lines, represent desired and undesired policy outcomes where violence finds a new sustained

equilibrium. These are at or below historical EQ levels for Hoped and higher than EQ for Feared. These reference modes are summarized in Table 2.

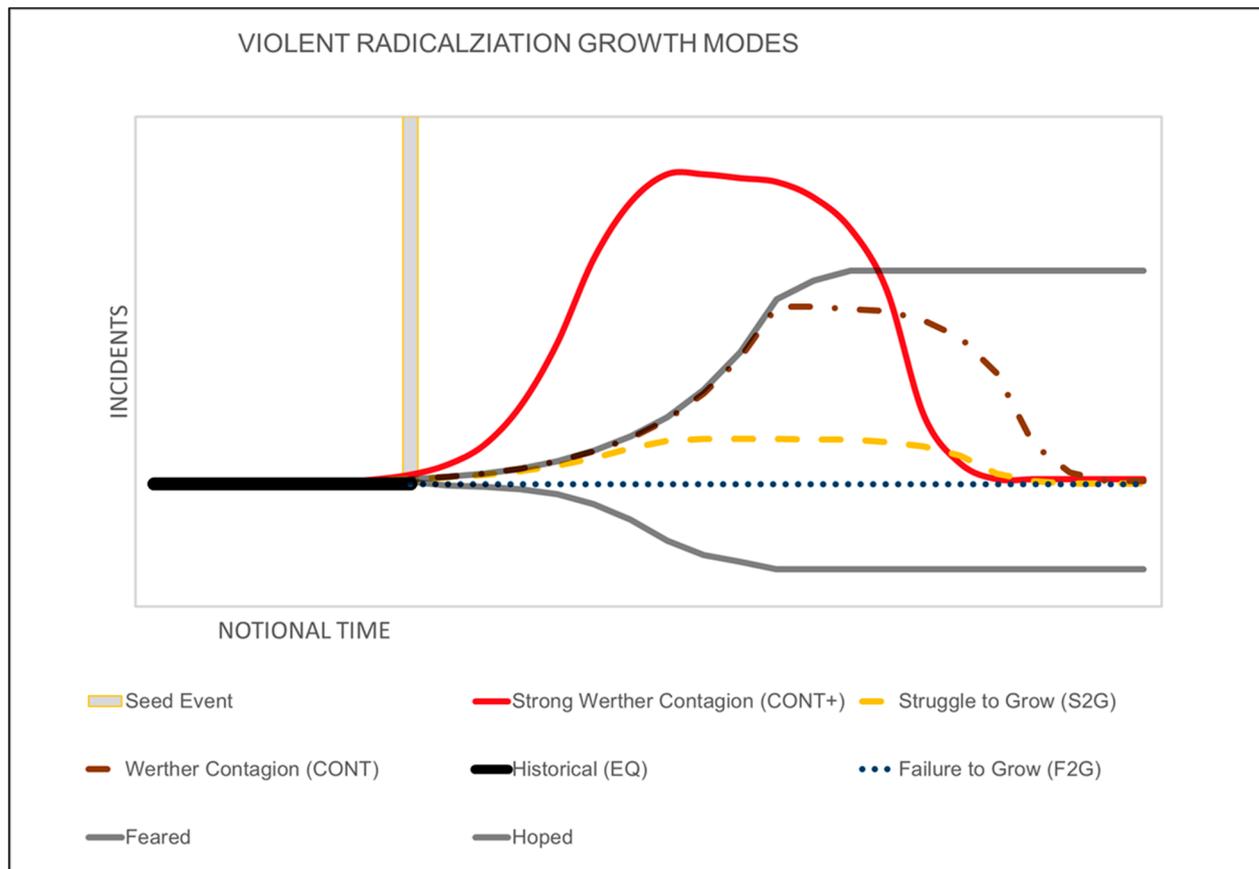


Figure 4. Terror contagion reference modes of growth.

Table 2. List of reference modes.

Reference Mode	Abbreviation	Description
Equilibrium	EQ	No terrorist violence can be distinguished from normal criminal violence before a seed event.
Failure to Grow	F2G	After a seed event, a terror contagion is difficult to distinguish from equilibrium.
Struggle to Grow	S2G	Limited growth from a seed event.
Contagion	CONT	Noticeable growth after a seed event.
Strong Contagion	CONT+	Strong growth and decline after a seed event.
Hoped		The desired policy outcome is where violence finds a new equilibrium at below-EQ levels.
Feared		The undesired policy outcome is where terrorist violence finds a new equilibrium at a higher level.

5. Terror Contagion Simulation

Our simulation is designed to test the terror contagion hypothesis as a model for understanding within DIME-PMESII standards. The simulation does not replicate or improve upon general terrorism simulations or models. In the simulation, an at-risk population is located in a larger society. At the beginning of the simulation, the at-risk population supports no violent ideology nor employs a template method. However, they may be engaging in normal criminal violence. The simulation is initiated in equilibrium and runs for 12 months before a seed event. The seed event is a single contagion incident—a terrorist attack communicating both template ideology and a template method. After the

seed event, the simulation runs for 9 years further, for a total of 10 years, to explore terror contagion dynamics.

Each simulation is initiated by importing a “profile.” A profile consists of the initial stock and parameter values. These include the success rates and average fatality rates of template methods, factors related to the at-risk population, and the extent to which this violent ideology is, or is not, supported by non-state actors in the ungoverned space. Profiles also contain policy response options activated as switches to test policy responses against a specific violent ideology. In this paper, the profiles are generic, using average values determined from prior research across a continuum of terrorist behavior identified in both the US and WEUR [9].

The full simulation model is developed and described in the supplementary materials. The structure and key sectors are presented in Figure 5, and select structures are described below.

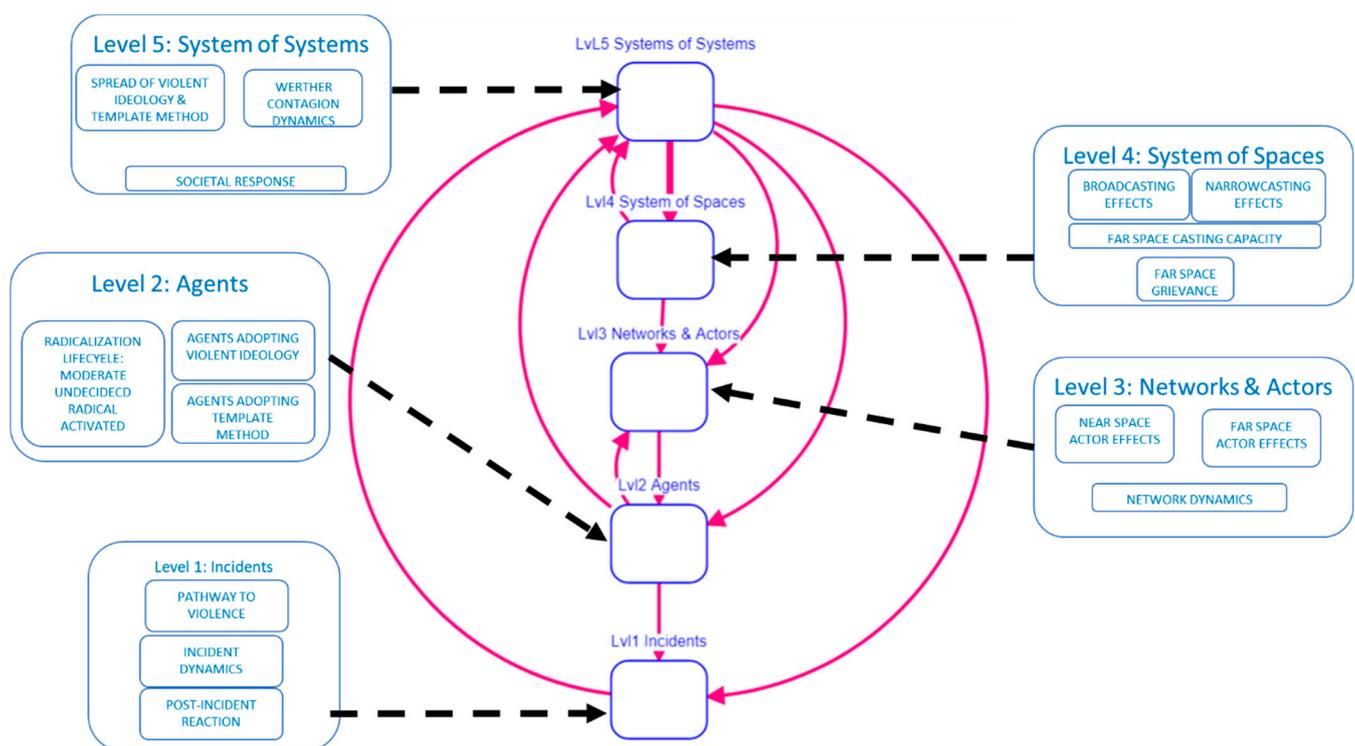


Figure 5. Terror contagion simulation structure and key sectors.

As a model for understanding, we leveraged existing published simulation model structures or generic structures where possible. For example, Level 2 Agents and Level 3 Network Dynamics are based on the FSB model as depicted in brown in Figures 6 and 7.

This structure depicts the transition of an at-risk population among different stocks, similar to FSB, except along a continuum of radicalization rather than profession, as in the original model. The at-risk population begins at 600 people distributed between states in the baseline runs, as shown in Table 3.

In equilibrium and base, this population is replenished at a constant addition of 10 People/Month into the Undecided State. However, this rate will be modified under some contingent experiments. State transition between moderate, undecided, radicalized, and activated is governed by network dynamics, including group identity taken from FSB shown in Figure 7.

FSB structure is depicted in brown. Additional influences are specific to our radicalization research, including the influence of non-state actors.

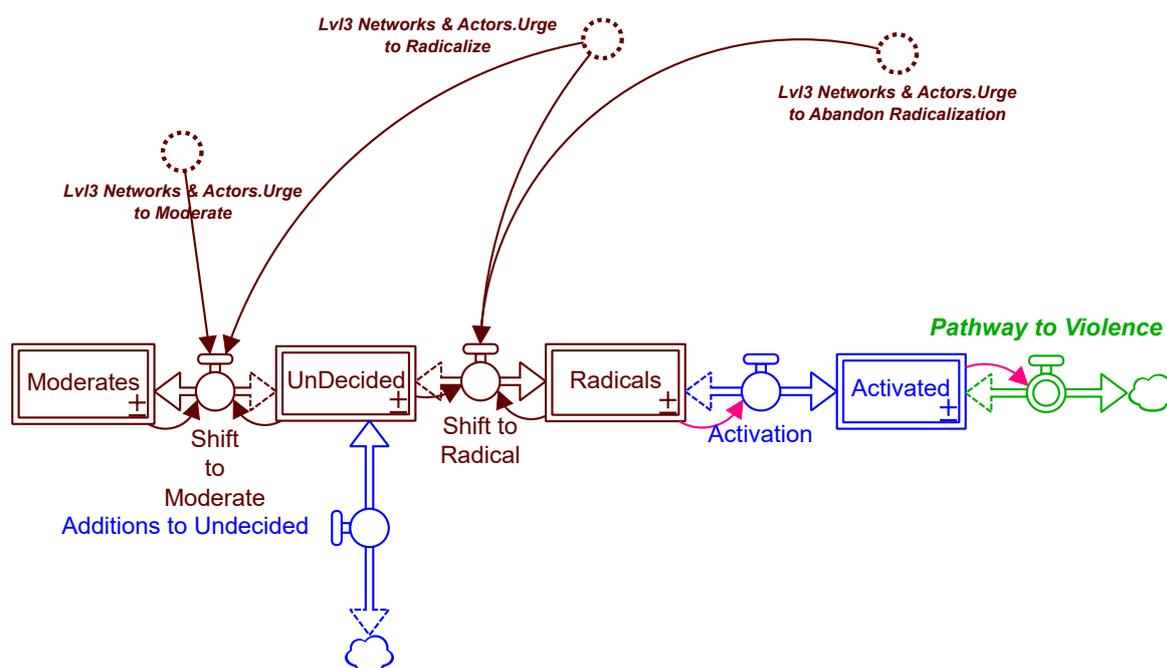


Figure 6. A simplified view of radicalization lifecycle structure in level 2 of the simulation.

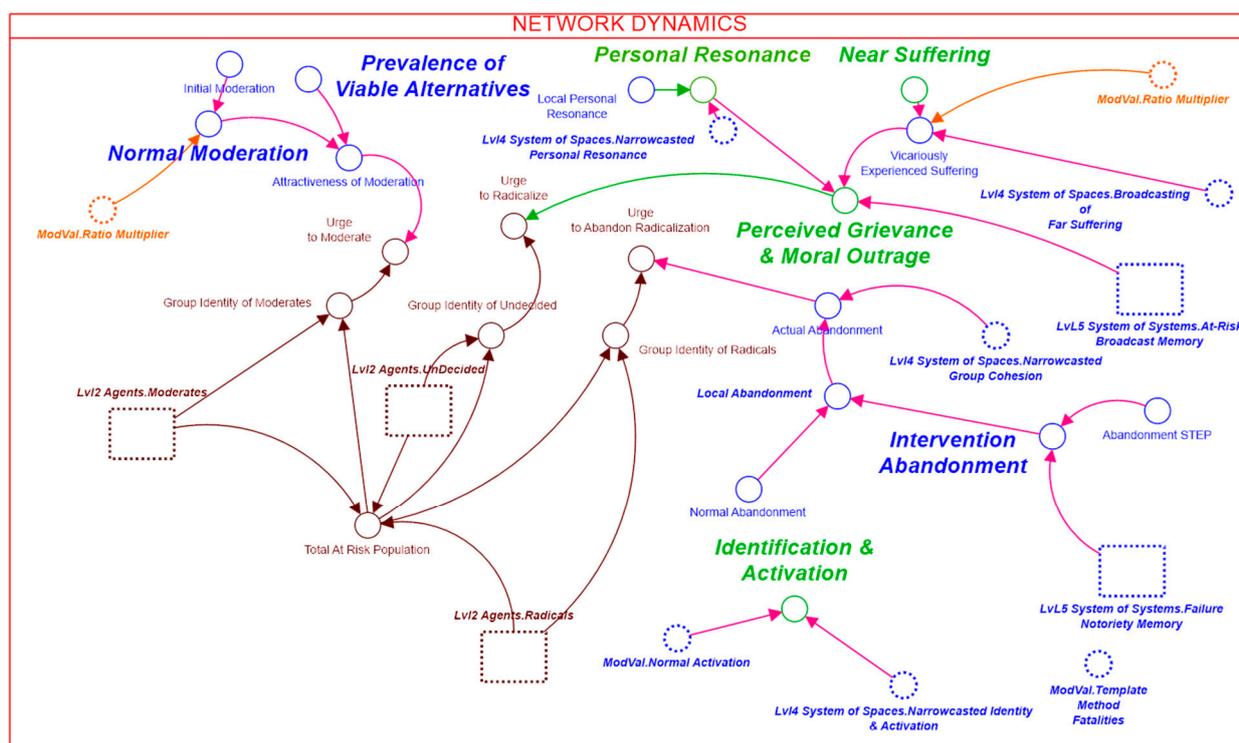


Figure 7. Simplified view of network dynamics structure in level 3 of the simulation.

Non-state actors casting radicalizing cultural scripts from a safe haven in ungoverned spaces can affect the at-risk population’s transitions. A switch in the profile turns on non-state actor presence and activates the simplified structure shown in Figure 8.

Table 3. Starting State Levels & Descriptions within an At-Risk Population.

State Level	People in State at Start	State Description
Moderate	200	Those who have adopted more moderate reactions to the perceived grievance and moral outrage.
Undecided	200	Those who have not responded to the perceived grievance and moral outrage. This state receives all new additions.
Radicalized	100	Those who have adopted a conspiracy narrative perspective on the perceived grievance and moral outrage.
Activated	100	Radicals who have begun the pathway to violence: planning, preparation, and intent to commit violent actions.

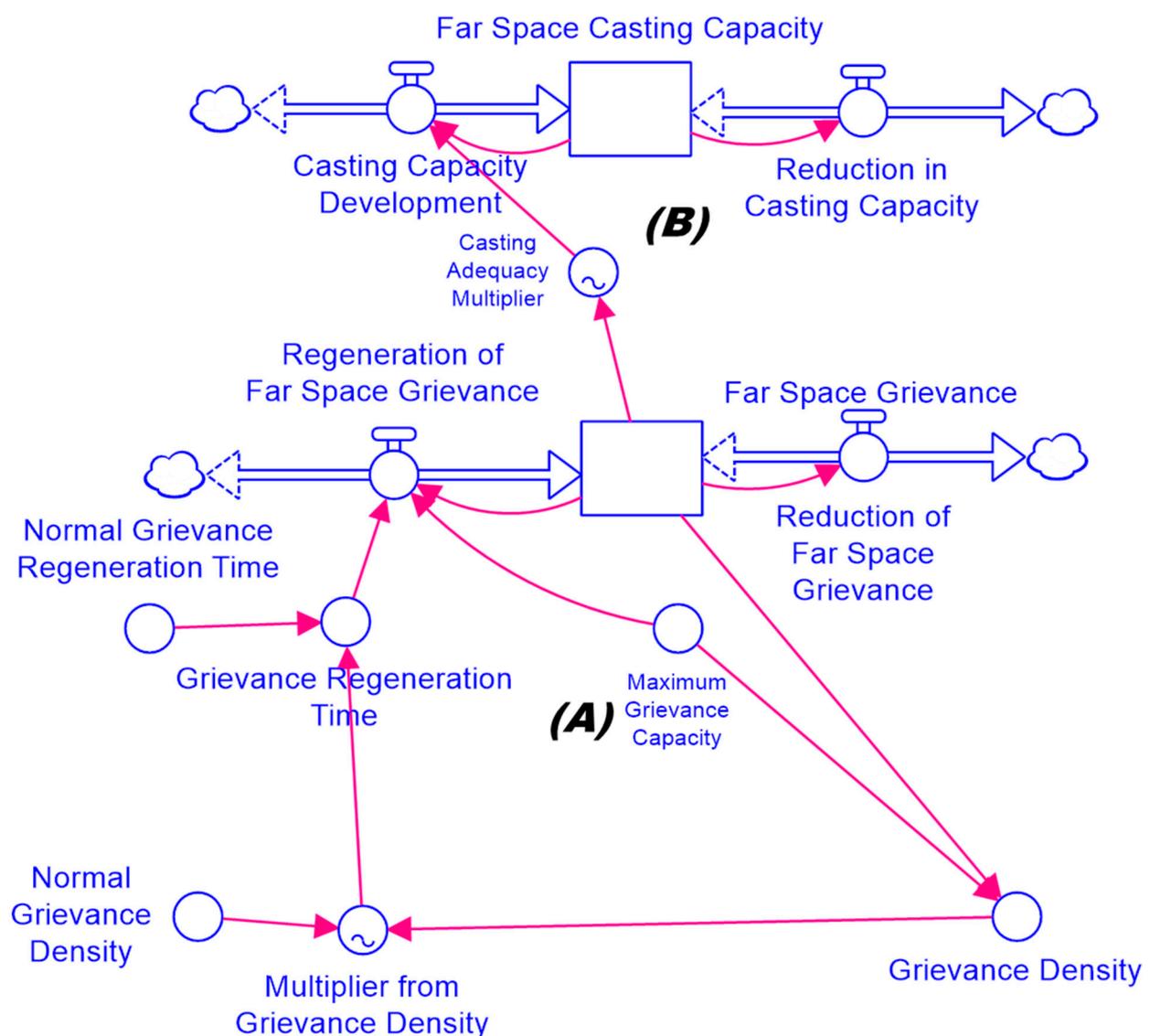


Figure 8. A simplified view of grievance & casting capacity structures in level 4 of the simulation. (A) organic regeneration structure representing long-term grievance in the ungoverned space. (B) implicit adjustment structure that determines level of casting capacity of non-state actors with adjustment mechanism driven by (A).

This structure leverages the generic structure for organic regeneration [48] to depict the long-term dynamics of grievance in an ungoverned space, as in Figure 8A. Grievance

then governs an implicit adjustment structure [48] to determine non-state actor casting capacity. Casting capacity is the aggregate ability of non-state actors to create cultural scripts and broadcast and narrowcast them into the governed space through literature, videos, and digital content. These influences reach the at-risk population through Level 3 Network Dynamics.

Although the overall model is continuously integrated when an activated person conducts terror incidents in Level 1, these are stochastically resolved using random number generators (RNG) as discrete events. These RNGs check against whether the perpetrator adopted a Template Ideology or Template Method, whether they succeeded in completing the terror incident, and whether they possess the evolutionary adaptation for predatory violence (currently set at 1). The model structure for terrorist incidents, with the location of RNGs highlighted in brown, is shown in Figure 9.

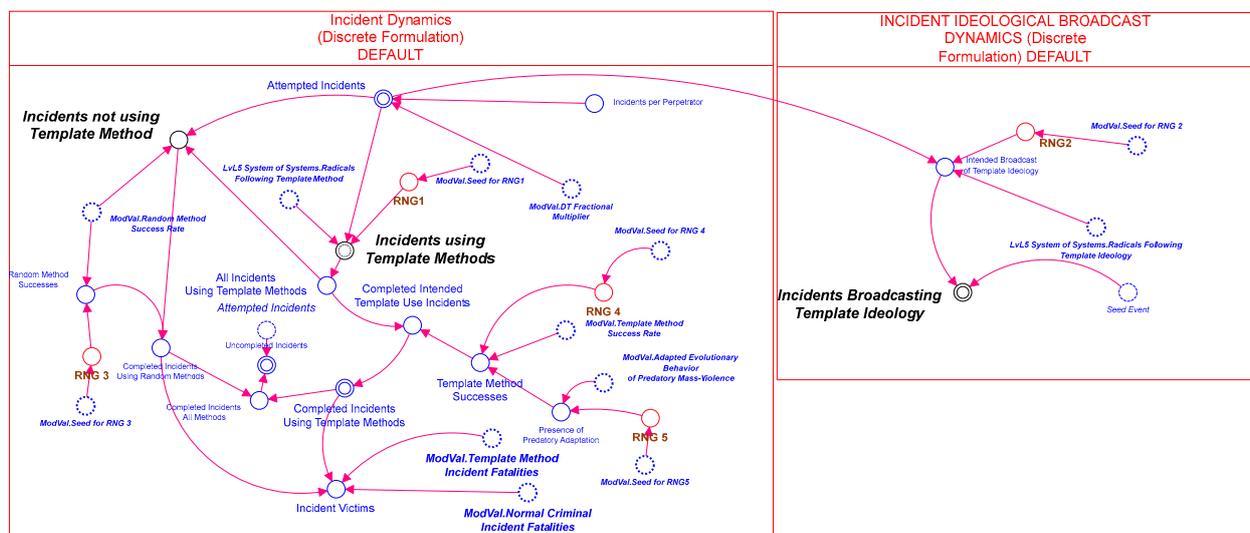


Figure 9. Simplified view of discrete formulation of incident dynamics, RNG's highlighted.

We recognize this approach will be controversial. This stochastic and discrete formulation of terror incidents within a larger continuous model reflects the terror contagion hypothesis as well as our findings from our research. Although we use the viral analogy to explain terror contagion, there are important differences. The sneezes and coughs which spread a virus are so ubiquitous and homogenous that they can be modeled as continuously occurring in the environment. Successfully completed terror incidents are discrete and rare. Terrorism, especially when segmented by ideology, doesn't occur every day, and the incidents are highly heterogenous, with widely varying completion and fatality rates based on small permutations that occur during the incident.

A continuous formulation of terror incidents suggests fractional terrorism each day and every day. A discrete formulation suggests a few successful incidents interspaced by long periods of inactivity with no completed incidents. The latter better reflects the historical record observed in Figure 3. Modeling terror incident outcomes correctly is important to the hypothesis we are exploring. The longer the period between completed high-fatality incidents, the greater the forgetting of the cultural scripts. This implies that, within a given channel of contingencies, only certain template ideology and template method combinations have a high enough fitness to sustain the contagion (see Channel experiments below.) The discrete formulation of terror incidents is also key for falsification to understand the mechanism of why some contagions fail. Level 1 Incident Dynamics is the only place where this approach is used. Terrorist incidents may be discrete events, but the radicalization and other effects resulting from them are continuous. (See Limitations below and our Supplementary Materials for further discussion on the discrete formulation).

Base Runs of the Simulation

To create the simulation base runs, we imported five profiles listed in Table 4. These profiles are generic abstractions and do not represent real-world violent ideologies. We minimized variations between the profiles to reduce misattribution. All but one of the following profile settings are held constant for each base run: an at-risk starting population of 600, an out-of-door incident success rate near the global average of 80% [9], and 10 fatalities per completed template method incident. The pathway to violence success rate, which is the chance an activated perpetrator will be stopped before “going out the door” during their planning stages, is the only one varied. We selected this because it represents a template method factor, allowing us to hold at-risk population values such as perception of near suffering, personal resonance to near suffering, normal activation, and normal abandonment constant. Additionally, the other template method factor, OTD success rate, does not vary substantially in our research of terrorism, with a global average approaching 80% [8].

Table 4. Base Run Settings.

RUN Name	Template Method Factors		At Risk Population Conditions			
	Pathway to Violence Success Rate	Out the Door (OTD) Success Rate	Perception of Near Suffering	Personal Resonance to Near Suffering	Normal Activation	Normal Abandonment
Equilibrium (EQ)	1	0.8	0.05	0.0	0.1	0.0
Failure to Grow (F2G)	0.1	0.8	0.05	0.0	0.1	0.0
Struggle to Grow (S2G)	0.2	0.8	0.05	0.0	0.1	0.0
Contagion (CONT)	0.5	0.8	0.05	0.0	0.1	0.0
Strong Contagion (CONT+)	1	0.8	0.05	0.0	0.1	0.0

We simulated 1000 permutations of each loaded profile, varying the RNG seed driving the stochastic outcome of the discrete terror incidents described above. Incidents can broadcast a template ideology, employ a template method, do both, or neither. However, contagion incidents are only counted when both template ideology and template method are present in the same incident. The numerical mean and range of contagion incidents across these 1000 permutations are listed in Table 5, along with the falsification characteristics we used to distinguish behavior modes.

All of the base runs are statistically different from one another (see Supplementary Materials for complete statistical analysis). However, because the range of Contagion Incidents can overlap, we adopted visual inspection criteria to help distinguish which behavior mode a contagion is operating in and improve falsification criteria.

In Figure 10, we see the behavior patterns within the Activated Population for reference modes EQ, F2G, S2G, CONT, and CONT+.

Visual inspection of Activated Population still does not distinguish some behavior modes, such as F2G versus EQ or certain S2G versus CONT cases. We visually inspect adoption rates in Template Ideology Figure 11 and Template Method Figure 12 as further criteria. The steeper the rate of adoption, the more severe a contagion.

CONT+ has a hockey-stick adoption rate to reach the limit of the population, while CONT and S2G both have an S-shaped growth. CONT and S2G are distinguishable by the time delay to complete the s-curve pattern. F2G shows an increasing concave behavior but never materializes into an S-Shaped pattern before the end of the simulation.

Table 5. Numerical Values of Base Runs at the end of Simulation after 1000 permutations.

Run Name	Falsifiable Characteristics	Value at DT 120	Attempts	Fails	Contagion	P-Value of Difference between Runs Based on Contagion Incidents
(1) EQ	Initial values = ending values in Activated. No Ideology or Method adoption.	Mean	118	117	0	NA
		Min/Max	NA	NA	NA	
(2) F2G	Zero to few Contagion Incidents. Limited adoption of Ideology or Method.	Mean	119.3	90.5	3.2	$p < 0.001$ vs. #3, #4, & #5.
		Min/Max	119–125	54–118.1	0–32	
(3) S2G	Zero to many Contagion Incidents. S-shaped adoption emerges in Ideology & Template adoption.	Mean	245.4	146.2	27.7	$p < 0.001$ vs. #2, #4, & #5.
		Min/Max	238–271	100.8–235.6	0–105	
(4) CONT	Many contagion events and clear cresting wave behavior in Activated. Ideology & Method clearly display S-shaped growth.	Mean	726.4	318.3	259.8	$p < 0.001$ vs. #2, #3, & #5.
		Min/Max	620–756	246.6–405.9	57–372	
(5) CONT+	Activated reaches sharp peak and decline while Template Ideology & Template Method display hockey-stick growth.	Mean	1540.2	591.62	704.8	$p < 0.001$ vs. #2, #3, & #4.
		Min/Max	1491–1544	511–770.7	469–806	

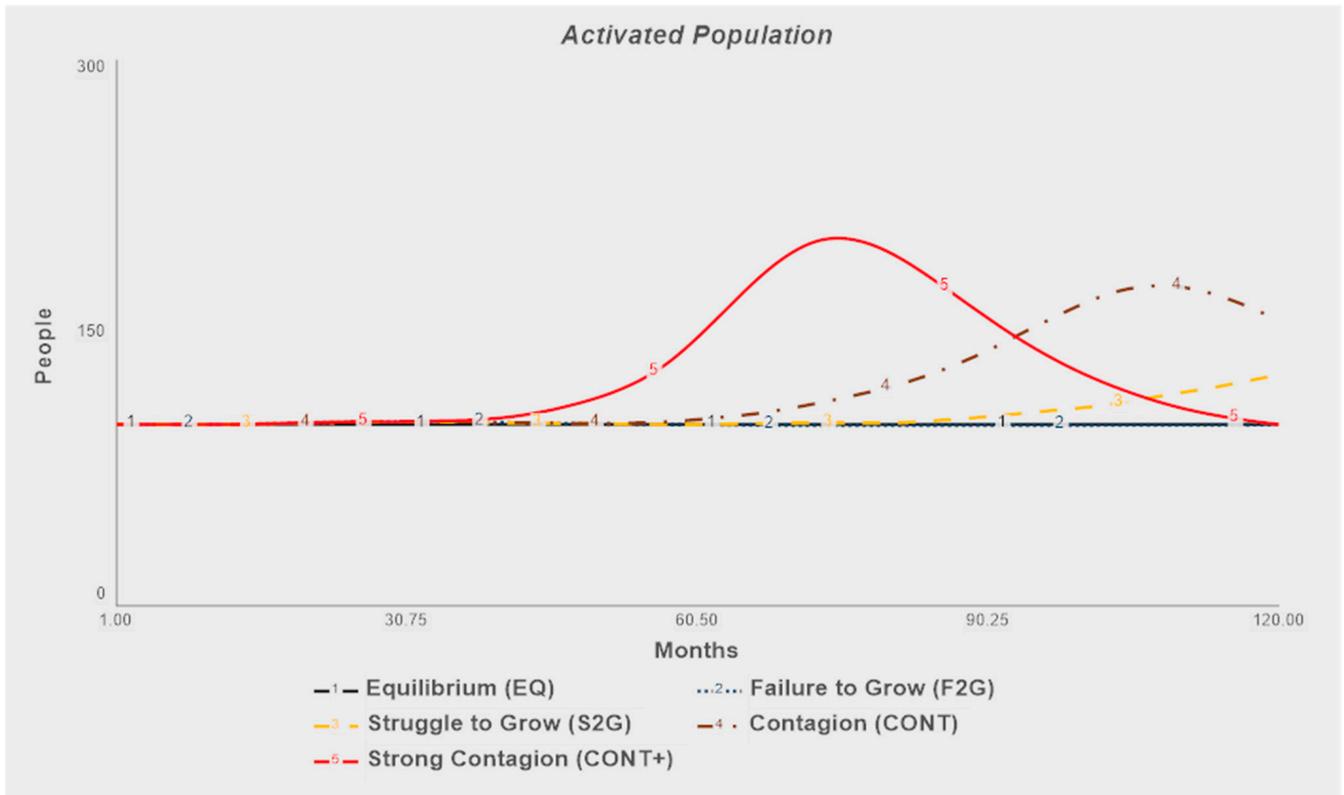


Figure 10. Activated population over base runs.

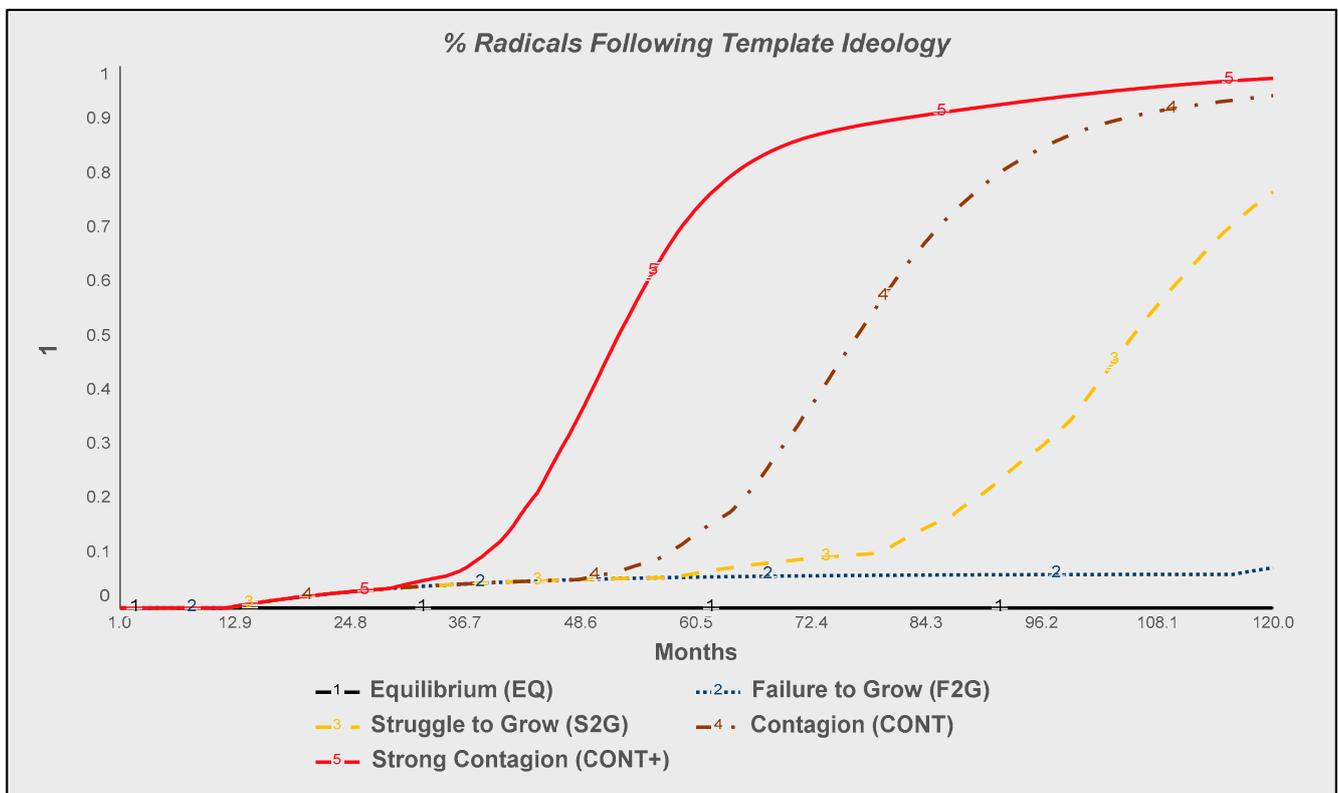


Figure 11. Adoption of template ideology across base runs.

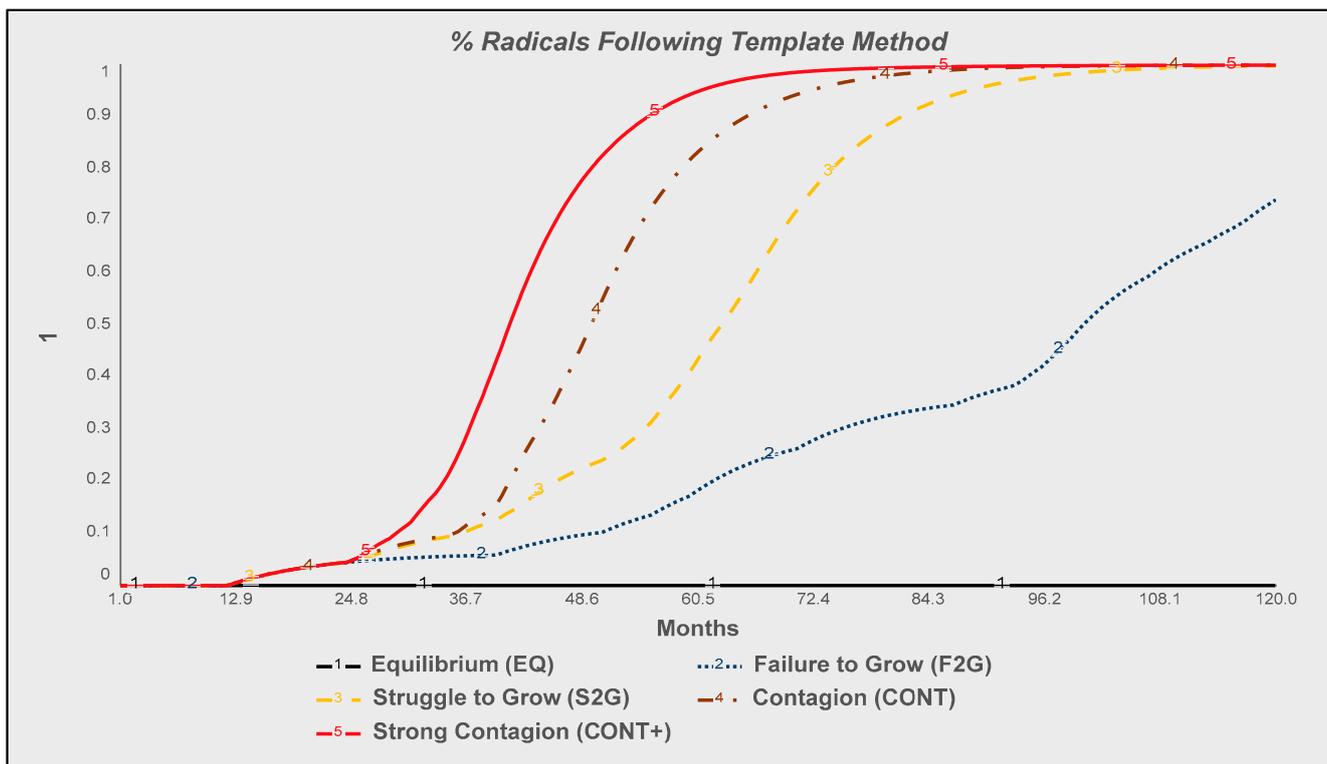


Figure 12. Adoption of template method across base runs.

6. Experimentation

Our method of contingency experimentation begins with a base run (usually CONT) and a change of model parameters related to one of the sixteen propositions. Results are shared in two tables. Table 6 lists the contingency values and dynamic changes for propositions #1–6 related to the terror contagion dynamic, all of which operate in Level 5 of the System. Table 7 lists the contingency values of propositions #7–18 located in Levels 1–4 of the system hierarchy.

Charts of every proposition test across a range of parameter values are included in the supplementary materials.

Table 6. Contingency analysis of propositions #1–#6.

Prop #	Parameter Tested	Baseline Tested	Baseline Value	Behavior Mode→	Below EQ	EQ	F2G	S2G	CONT	CONT+	Range Tested & Notes
NA	NA			Range Across 100k Permutations→		0	0–32	0–105	57–372	469–806	CONT = Contagion
1	Template Attractiveness for Social Contagion	CONT	100%	Range		0	0–13	0–72	216–234		0–100% @ 10% Increments
				Result		0%	0–50%	50–90%	90–100%		
2	Near Suffering	CONT	5%	Range		0	NA	22	113–277		0–10% @ 1% Increments. Diminishing returns for Near Suffering > 10% and even 100% stays in CONT range.
				Result		0%	NA	1%	2%+		
3	Template Method	CONT	100%	Range		0	0	10–45	175–247		0–100% in 10% increments. As long as Template Ideology > 0%.
				Result		0%	10–20%	20–40%	40–100%		
4	Template Ideology	CONT	100%	Range		0	0–6	80–107	159–234		0–100% in 10% increments. As long as Template Method > 0%.
				Result		0%	10–30%	30–50%	50–100%		
5	Biological Adaptation to Predatory Mass Violence	CONT	100%	Range		0	1–6	20–85	201–234		0–100% @ 10% increments.
				Result		0%	10–20%	30–70%	80–100%		
6	Media Power Experimental Value	CONT	100%	Range		0	30	61–101	130–400	404–420	0–10% in 1% increments, 10–100% in 10% increments. 100% reverts back down to CONT behavior mode.
				Result		0%	1%	2–7%	8–40% & 100%	40–90%	

Table 7. Contingency analysis of propositions #7–#16.

Prop #	Parameter Tested	Baseline Tested	Baseline Value	Behavior Mode→	Below EQ	EQ	F2G	S2G	CONT	CONT+	Range Tested & Notes
NA	NA			Range Across 100k Permutations→		0	0–32	0–105	57–372	469–806	CONT = Contagion
7	Multiplier for Population	CONT	x1 (600 People)	Range			0–1	37–72	153–1581	2080–4364	×0.1 to ×10 (60–60,000 at-risk Population) in increments of 0.1. Behavior modes are determined by falsification criteria, not incident ranges, as increased populations naturally move values out of baseline ranges.
				Result			60–120	120–360	360–3000	3000–30,000	
8A	Safe Haven Casting Capacity (Broadcast)	CONT	0%	Range					234–452		Broadcast casting Power 0–100% @ 10% increments. CONT begins to shift to CONT+ at 30%+, but adoption rates remain S-curve and do not change to hockey-stick of CONT+
				Result					0–100%		
8B	Safe Haven Casting Capacity (Narrowcast)	CONT	0%	Range					234–424		Narrowcast casting power 0–100% @ 10%. CONT begins to shift to CONT+ at 30%+, but adoption rates remain S-curve and do not change to hockey-stick of CONT+
				Result					0–100%		
8C	Safe Haven Casting Capacity (Both)	CONT	0%	Range					234–443	446–492	Broadcast & Narrowcast factors 0–100% @ 10% increments. Clear transition from CONT to CONT+ at 30%+ Power in both contagion incident counts and adoption rate behavior shapes.
				Result					0–30%	30–100%	
8D	Safe Haven Casting Capacity (Both)	S2G	0%	Range				37–114	141–190		Broadcast & Narrowcast factors 0–100% @ 10% increments. S2G mode escalates to CONT at combined power of 20%+.
				Result				0–20%	20–100%		

Table 7. Cont.

Prop #	Parameter Tested	Baseline Tested	Baseline Value	Behavior Mode→	Below EQ	EQ	F2G	S2G	CONT	CONT+	Range Tested & Notes
9	Moderating Alternatives	CONT	5%	Range					102–257		0–100% in increments of 10%. As moderating alternatives increase, contagion severity declines within the range of that contagion. Still, it does not shift behavior to a new contagion shape.
				Result		0%	1%	2–7%	8–40% & 100%	40–90%	
10	Abandonment Rate	CONT	0%	Range	0		7	97	234		0–30% in increments of 5%. 15%+ Abandonment creates a sub-EQ result with increased growth in Undecided and Moderates.
				Result	15–30%		10%	0–5%	0%		
11	Activation Rate	CONT	10%	Range	0		28	75	123–328		0–10% in increments of 1%, 10–100% in increments of 10%. CONT emerges 5–10%, 20–100% show initial bumps then CONT. Victim rates increase until 30% Activation, at which point they decline slightly. This is because too high an Activation drains the Radicals too fast, negatively impacting network effects, though this effect is minor.
				Result	0%		0–1%	1–2%	3–100%		
12	Ratio Multiplier of Non-radicalized to Radicalized	CONT	1 (2:1)	Range			0	52.4–71.4	52–364		×0.1–×2.0 @ increments of 0.1.
				Result			×1.4, 1.5, 1.7–2.0	×0.1–0.2	×0.2–1.4		

Table 7. Cont.

Prop #	Parameter Tested	Baseline Tested	Baseline Value	Behavior Mode→	Below EQ	EQ	F2G	S2G	CONT	CONT+	Range Tested & Notes
13	Pathway to Violence Time	CONT	10	Range					48–421		1–24 Months @ 1 month Increments. Given a fixed population with fixed replacement, and all else being equal, altering time for the pathway to violence alters the draining rate at which the population will be converted to Activated. This moves Activated peak and decline left and right and adjusts incident rates, but all within the CONT behavior.
				Result					1–24		
14	Template Method Pathway to Violence Success Rate	CONT	50%	Range		0	1	37–72	161–383	472–695	0–100% @ increments of 10%.
				Result		0%	0–10%	10–40%	40–70%	70–100%	
15	Template Method OTD Success Rates	CONT	80%	Range		0	0	29–95	212–336		0–100% in Increments of 10%.
				Result		0%	1%	2–7%	8–40% & 100%	40–90%	
16	Template Method Fatality Rates	CONT	10	Range		0	0	0–48	234–377	392–477	0–21 Fatalities @ increments of 1 Fatality
				Result		0–5	5–7	8–9	10–12	13–21	

7. Discussion

7.1. Strong, Moderate & Weak Propositions of Terror Contagions

Using the criteria described above, we classified the 16 testable propositions into Strong, Moderate, and Weak categories in Table 8. A strong proposition has a contingency range that completely eliminates a base Contagion (CONT) dynamic, taking it back to or below the Equilibrium (EQ) mode both numerically and on visual inspection. A moderate proposition can strengthen or weaken a Contagion between the modes but not eliminate it based on contingencies. A weak proposition may adjust the final number of contagion incidents but not move it out of the range of the base model.

Table 8. Proposition Influences on Contagion based on Contingency Values.

Strong Propositions: Can eliminate Contagions.		Moderate Propositions: Can Strengthen/Weaken Contagions.		Weak Propositions: Cannot Change Base Behavior Mode of Contagion.	
ID	Propositions	ID	Propositions	ID	Propositions
1	Template Attractiveness for Social Contagion	7	Size of At-Risk Population	8A	Non-State Actors using Safe Havens to only Broadcast (CONT)
2	Perceived Grievance & Moral Outrage	8C	Non-State Actors using Safe Havens to both Broadcast & Narrow Cultural Scripts (CONT)	8B	Non-State Actors using Safe Havens to only Narrow Cultural Scripts (S2G)
3	Template Method	8D	Non-State Actors using Safe Havens to both Broadcast & Narrow Cultural Scripts (S2G)	9	Moderating Alternatives
4	Template Ideology	10	Abandonment Rate	16	Template Fatality Rates
5	Biological Adaptation to Predatory Mass Violence	11	Activation Rate		
6	Media Reach	12	The Ratio of Radicalized to Non-Radicalized in an At-Risk Population.		
11	Activation Rate	13	Time to Complete Pathway to Violence		
16	Template Fatality Rates	14	Template Method Pathway to Violence Success Rate		
		15	Template Method OTD Success Rates		

7.2. Root Causes of Terror Contagion

Six of the eight strong propositions reside in Level 5: System of Systems and correspond with our terror contagion hypothesis elements. The remaining two, Activation Rate and Template Fatality Rates, are subsequent causes of the original six. This is because Template Ideology determines Activation and the Template Method influences the average fatalities for a completed mass-violence incident. This builds confidence that these strong propositions, when combined, are the true root causes of predatory mass violence, as the absence of any single strong proposition means no terror contagion will occur.

A surprise finding is the weak influence of the duration of the pathway to violence. This finding may result from the success rates of pathways to violence being tested separately from their duration. When success rates are held constant, the time spent on a pathway becomes immaterial between 1–24 months. We suspect that what matters most is the relation between the preparation time the template method requires and the success rates enabled by that preparation, rather than the overall time itself.

Proposition #8, using a Non-State actor in a safe haven, was a special case. Broadcasting or narrowcasting alone (#8A & #8B) were weak propositions, unable to shift contagion modes. The contagion incidents may have grown or declined but still fall within the range

of the original contagion mode. However, combining broadcasting and narrowcasting strengthened a contagion base mode such as Struggle to Grow (S2G) to a higher mode such as CONT under certain contingencies. We explore this special case further in our Channel Experiment below.

7.3. Contagions Require a Combination of Template Ideology & Template Method

Our findings indicate that a template ideology and method must be present for contagion to exist. To demonstrate this, we vary the power of Template Ideology and Template Method independently and present the results in Figure 13.

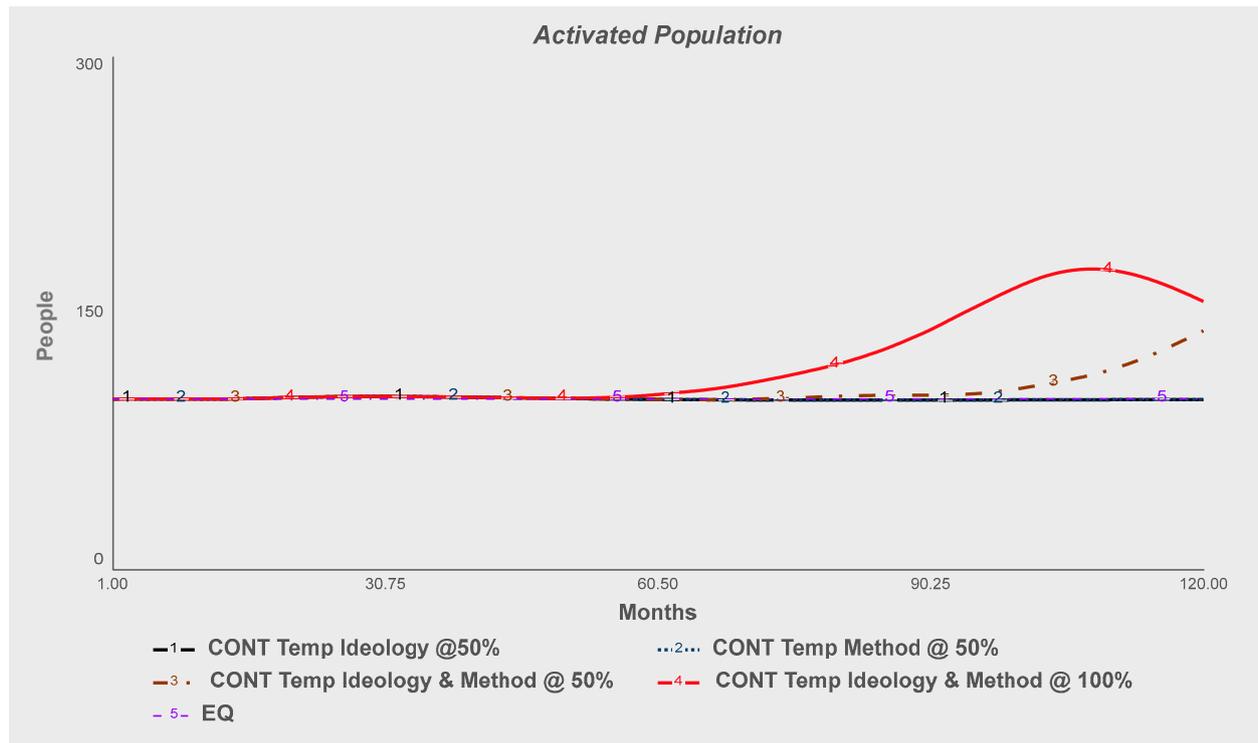


Figure 13. Template ideology & template method contingency results on an activated population.

Even if Template Ideology or Template Method is at 50% power in isolation, the behavior of Activated Population remains the same as Equilibrium (EQ). Only when combined do they show the contagion behavior (CONT). Why must template ideology and method be paired together for a successful contagion? We explore this in two parts below.

7.4. Why Template Ideology Requires Template Method: Fatalities & Media Reach

Template Ideology requires combination with Template Method, which relates to the number of fatalities an incident produces and how that incident is subsequently reported by the media. In Figure 14, the Template Method Average Fatalities for CONT is modified between 0–21 at increments of 1 fatality, displaying behavior modes similar to the numerical findings in Table 7 #16. When Average Template Fatalities are low (<5), the CONT Behavior Mode is knocked out of the contagion pattern to EQ. Between 5–7 fatalities, the behavior mode of CONT weakens to F2G, and 8–9 fatalities weakens to an S2G.

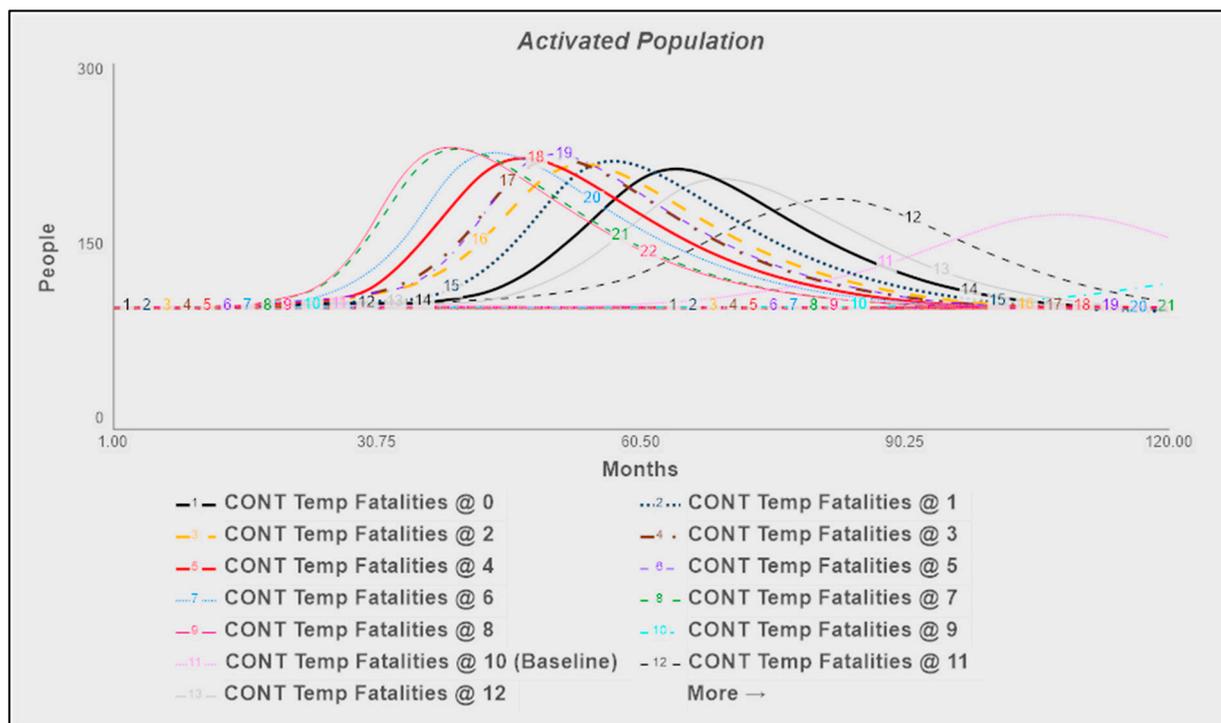


Figure 14. Variation of fatality rates on CONT run.

Between 10–12 fatalities is the threshold for CONT behavior. When average fatalities reach 13–21 a CONT+ behavior emerges. However there are diminishing marginal increases for each additional fatality in this range. This is because there are only ever a finite number of at-risk population. Once a certain threshold of fatalities is reached, the media reporting reaches the entirety of the population and marginal increases in fatality will not return similar marginal increases in contagion strength.

However, high fatality rates require a sufficient one-to-many broadcast effect to fuel contagions, as shown in Figure 15. This graph demonstrates the effective broadcast reach of media to the at-risk population, 0–100% at increments of 10%, and the baseline CONT behavior being at 100% reach. As media coverage drops to only reach a quarter of the at-risk population (25%), the CONT behavior mode weakens into a Struggle to Grow (S2G) behavior mode.

These two effects show why Template Ideology alone cannot provoke a terror contagion. The high fatalities of a Template Method vary significantly from normal criminal violence, which drives the media to conduct one-to-many reporting. That reporting must be of sufficient power to reach enough of the target at-risk audience. This may also explain why terror contagions by individuals are relatively new phenomena. In the past, without modern equipment, including destructive devices and weaponry, an individual's ability to create sufficient fatalities was limited. Even if this did happen, the reach of the media to spread it widely enough to spark replication in an at-risk population would not occur soon enough to sustain the terror contagion.

7.5. Why Template Method Requires Template Ideology: Template Attractiveness

The requirement for Template Methods to combine with Template Ideology in order for a terror contagion to occur relates to the contingencies of Template Attractiveness. This is an aggregate measure of notoriety, self-similarity, and template cohesion components. At 0%, none of the at-risk population will find the template attractive. At 100%, the entirety of the at-risk population will find the cultural scripts attractive, even if they have not adopted a radical position. As depicted in Figure 16, the Template Attractiveness is varied between 0–1 at increments of 0.1.

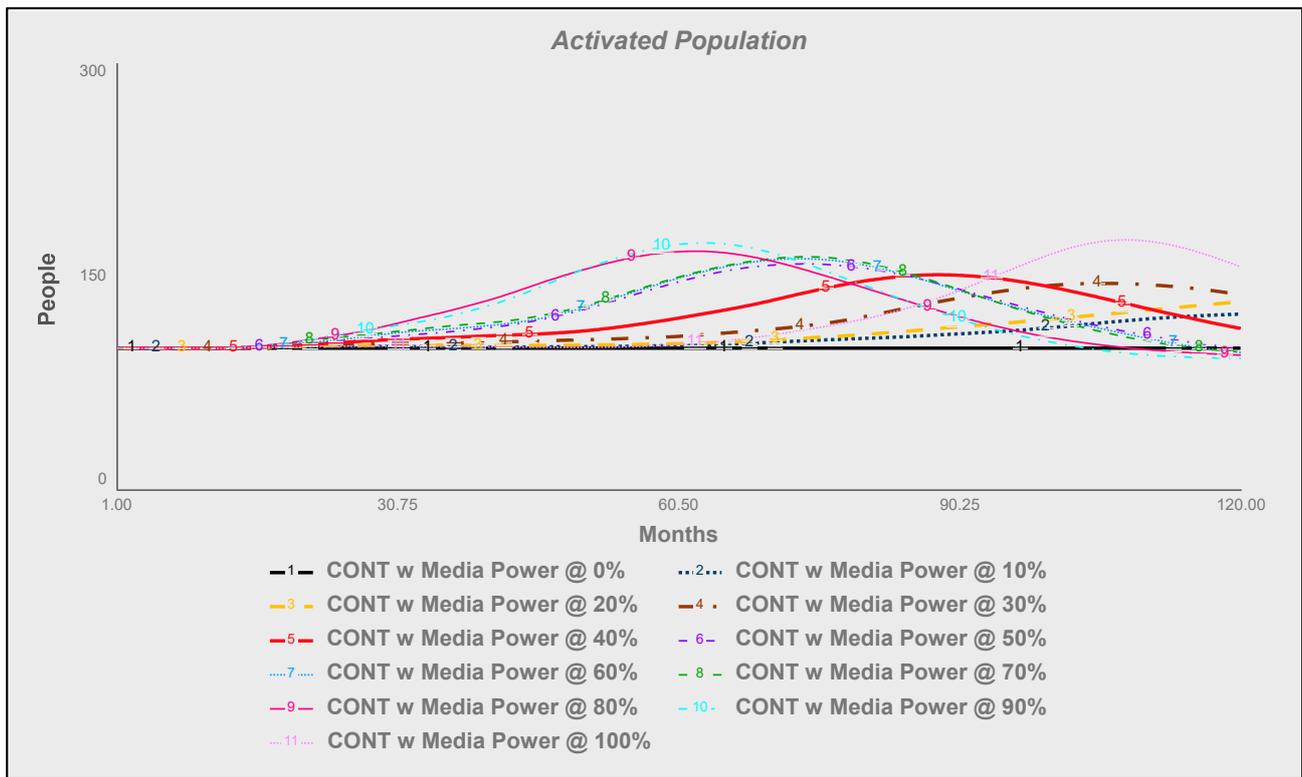


Figure 15. Sensitivity of media broadcast power on CONT run.

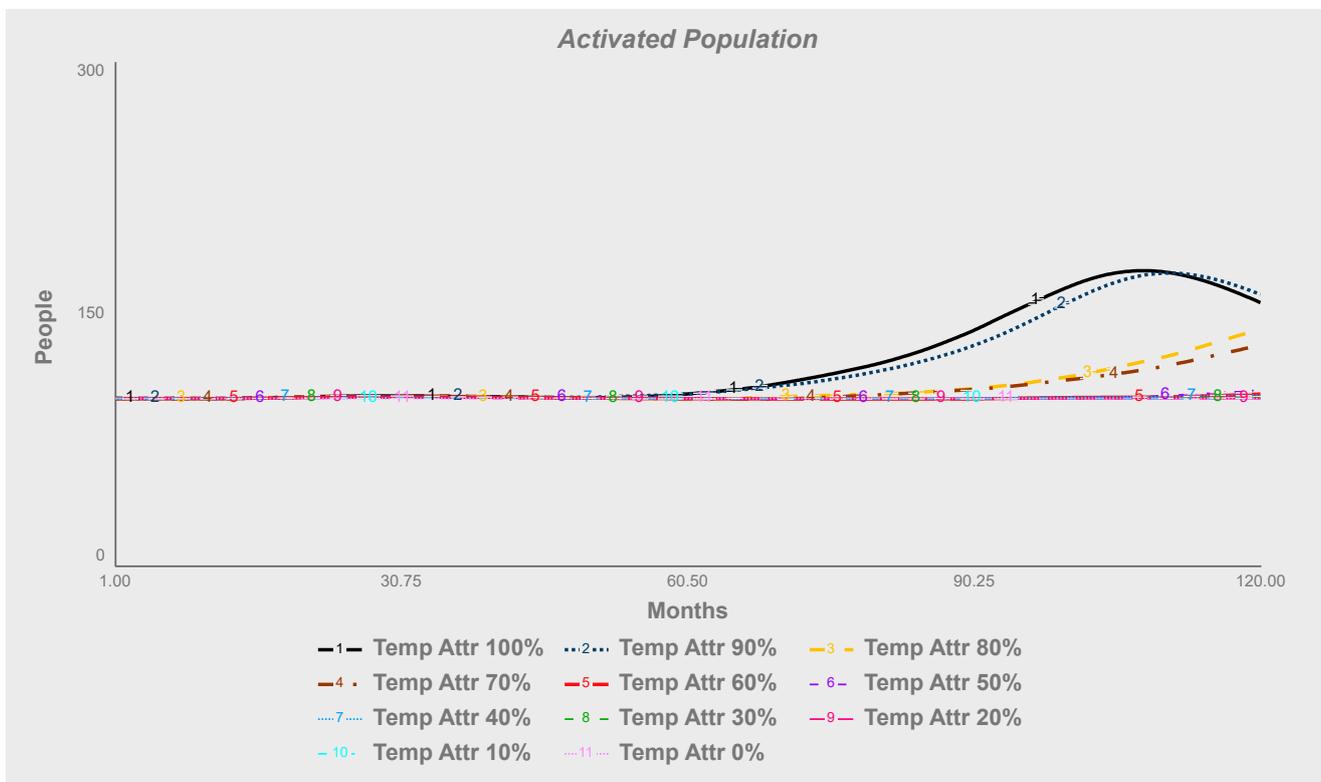


Figure 16. Template attractiveness power varied.

In Figure 16, when Template Attractiveness is 0%, the CONT reduces to EQ. Even when incidents are committed randomly with a Template Ideology and Template Method,

the at-risk population cannot recognize and discern it as applying to them. As Template Attractiveness reaches < 90%, the CONT behavior reduces to S2G. At 50%, the S2G behavior shifts to F2G. This indicates that the power of Template Attractiveness need not be at 100% to be effective. When enough of the at-risk population receives the signals and replicates the broadcasting of Template Ideology and Method, the at-risk Broadcast Memory accumulates faster than it is forgotten, as shown in Figure 17.

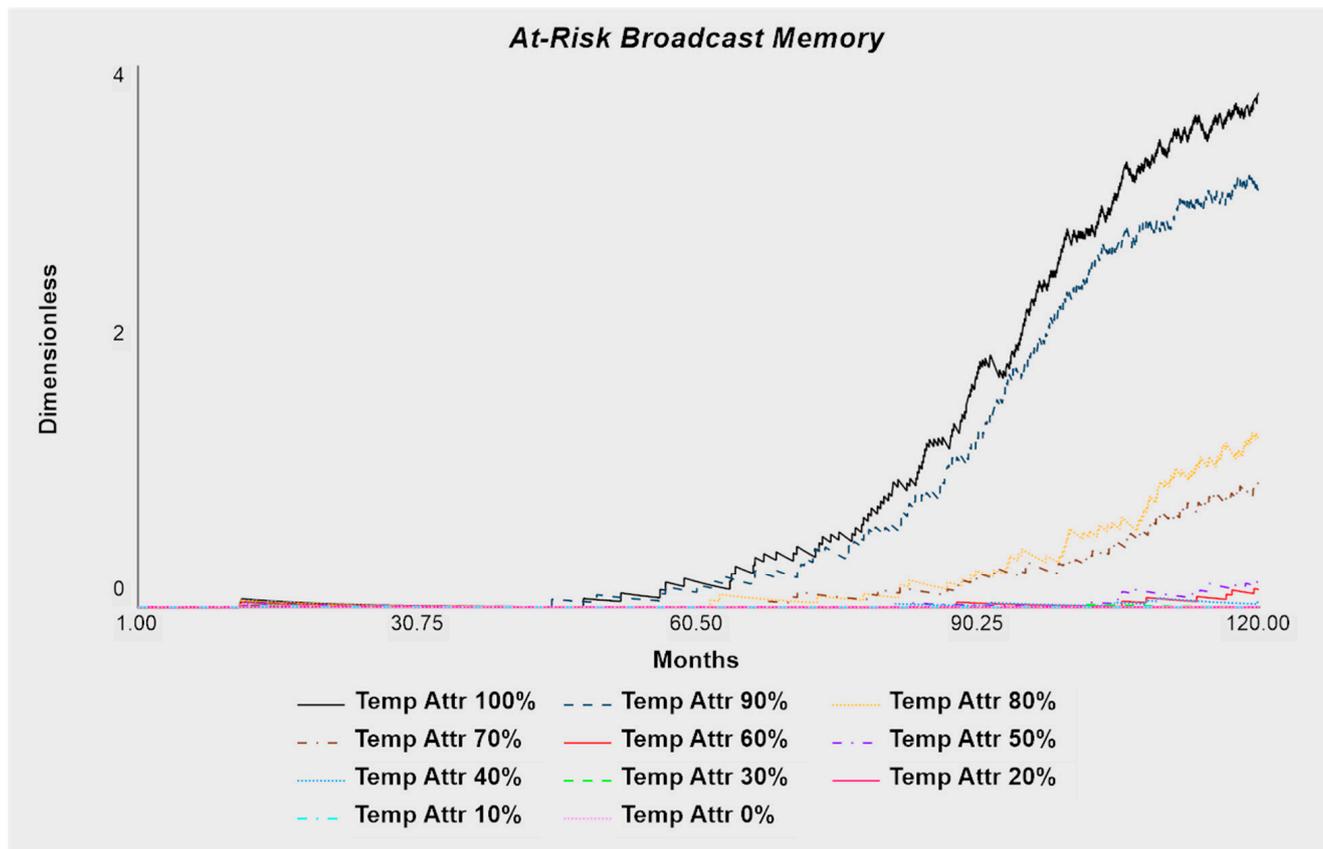


Figure 17. At-risk population broadcast memory on CONT run as template attractiveness varies 0–100%.

Broadcast memory is the collective “memory” of the at-risk population that stores cultural scripts relating to template ideology and memory. It is increased by successful media reporting of mass-violence incidents and naturally declines through forgetting over time.

Template Attractiveness also explains why Template Methods alone cannot provoke a terror contagion. The Template Ideology is the vehicle that communicates cultural scripts by providing a conspiracy narrative that resonates with the perceived grievance and moral outrage of the at-risk population who see themselves in these actions and find them to possess notorious celebrity. Templates must also be well-cohered or reified. A Template Ideology or Method that cannot be discerned from a normal criminal incident provides no path for replication. This suggests that, in terms of selecting a modus operandi, like follows like. At-risk populations do not conduct a rational all-sources search to identify the objectively optimal means to mass violence available to them. Instead, based on heuristics, they replicate what those in whom they find self-similarity and notoriety have done in the past.

7.6. Contagions Have a Low Threshold to Form

A key finding of the propositions tests is the low threshold for a terror contagion. An at-risk population of 360–3000 people, of whom at least a small fraction are mobilized by a

grievance, can generate a terror contagion, even when, to begin with, the non-radicalized members of the at-risk population greatly outnumber the radicalized,. The Template Method of mass violence does not need to be sophisticated or foolproof. As long as activated perpetrators can complete their pathway to violence preparations > 40% of the time and the incidents themselves successfully complete >60% of the time, reliably producing an average of 10–12 fatalities, a CONT behavior will emerge. The global average for the successful completion of terrorist incidents once they are begun is close to 80% [9].

7.7. Channel Experiment: Resolving the Swarm vs. Fishermen Debate

An important finding of our work may help resolve the swarm vs. fishermen debate. A channel, in our terms, is a space within the terror contagion system suitable for certain types of manifestations. The presence of six strong propositions creates the channel. The remaining moderate and weak propositions determine its nature and shape.

Swarm radicalization manifests within a channel where the contingent values of these propositions are sufficiently high that no outside influence is required to generate a CONT behavior. However, when these contingent values are low, a channel exists within which a contagion could form, but local conditions are insufficient to sustain it. Non-state actors casting cultural scripts from the ungoverned space into the governed space, however, can strengthen the weaker contagion, shifting it in behavior mode from Struggle to Grow (S2G) into a Contagion (CONT). This combination of contingencies would result in the attribution of a fishermen dynamic as a cause of radicalization, rather than a channel's byproduct. We believe this occurred in the historical debate due to a focus on Salafi-takfiri violent ideology in the US and WEUR, where at-risk populations would be smaller. In an experiment, we set contingent values to create channels to replicate these conditions in Table 9. For this experiment, we used all six strong propositions and two moderate propositions (at-risk population and presence of a non-state actor), which are the fewest number of propositions necessary to replicate the swarm and fishermen manifestations.

Table 9. Contingency Values for Swarm vs. Fishermen Channels.

Prop ID	Proposition	Contingencies to Create Swarm Channel	Contingencies to Create Fishermen Channel
1	Template Attractiveness for Social Contagion	100%	100%
2	Perceived Grievance & Moral Outrage	5%	5%
3	Template Ideology	100%	100%
4	Template Method	100%	100%
5	Biological Adaptation to Predatory Mass Violence	100%	100%
6	Media Reach	100%	100%
7	At-Risk Population	600 People	300 People
8	Non-State Actor Casting Capacity	0	0 & 1

In both channels of Table 9, all but two of the contingent values for Propositions 1–8 are set at levels sufficient to recreate the baseline terror contagion (CONT). The contingent size of the at-risk population remains at baseline values (600 People) for the swarm channel. It is reduced by half (300 People) for the fishermen channel. We ran three simulations, one within the swarm channel and two within the fishermen channel. The results are displayed in Figure 18. The difference between the two fishermen simulations is in the value of non-state actor (NSA) casting capacity, set at 0 and 1, representing 0% cultural-script casting into the governed space from the ungoverned and 100%, respectively.

The fishermen channel demonstrates an S2G behavior mode when the at-risk population is half the baseline and there is no non-state actor support. However, when non-state-actor-cultural-script casting is added at 100%, it returns to a CONT behavior, as shown by the number of contagion incidents in Table 10.

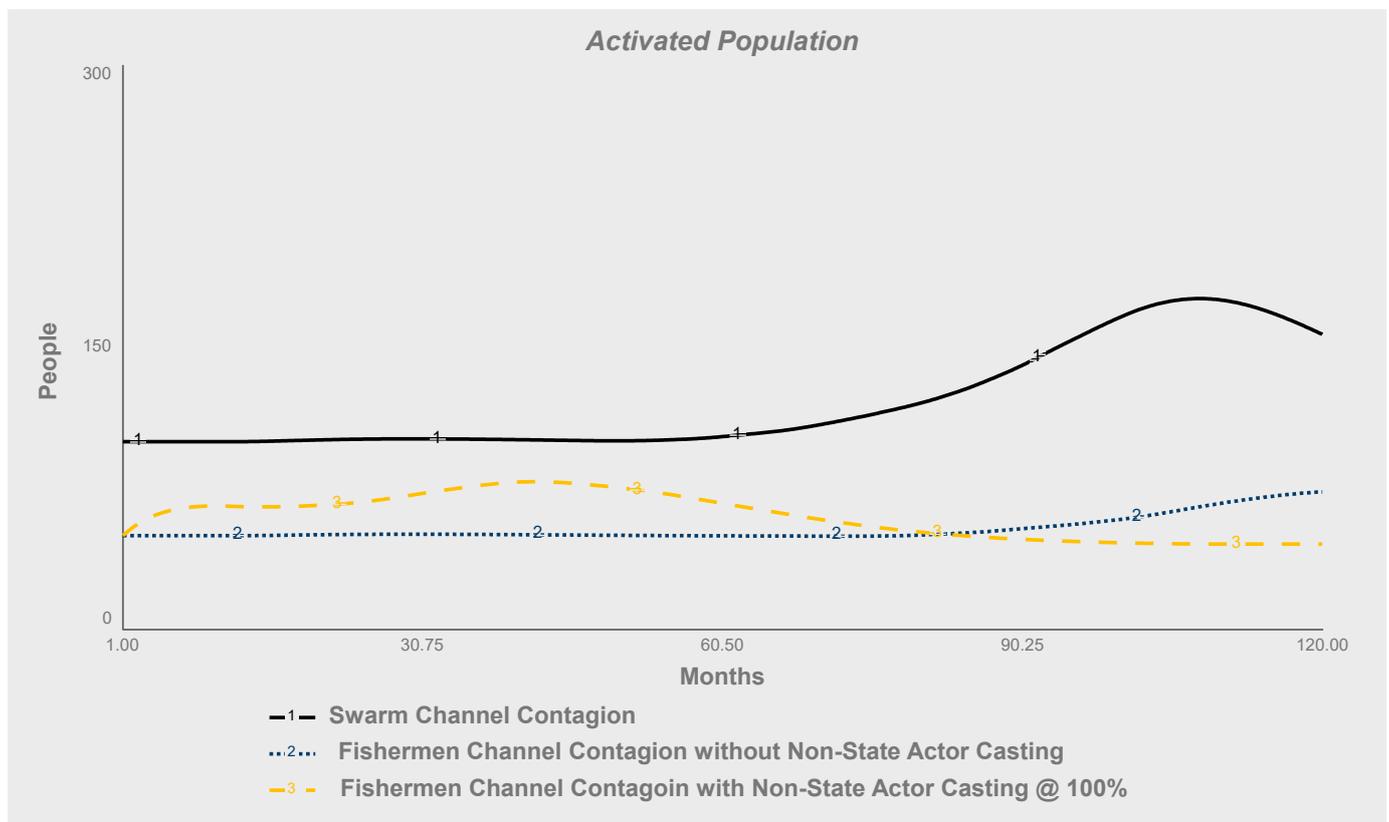


Figure 18. Channeling effect swarm (CONT) vs. fishermen contingencies (S2G shifting to CONT).

Table 10. Numerical values of channel behaviors at simulation end.

Run	Total Attempted Incidents	Failed Incidents	Total Contagion Incidents
Swarm Channel Contagion	719	342.4	234
Fishermen Channel Contagion without Non-State Actor Casting	318	186.6	60
Fishermen Channel Contagion with Non-State Actor Casting @ 100%	360	113.7	224

Even though the at-risk population of the Fishermen contagions is half that of Swarm, when a non-state actor is casting at 100%, the final Contagion Incidents for both are nearly the same. Template Ideology and Template Method adoption within the at-risk population demonstrates how the contingencies of those channels shape the manifestation, as shown in Figure 19.

For the swarm channel in Figure 19, the adoption of template ideology arises organically over time and in response to successfully completed contagion incidents only. Additionally, a fishermen channel of a smaller population without non-state actor casting spreads the ideology more slowly for the fewer contagion incidents that occur. However, in the figure above, as well as Figure 20 below, the non-state actor operating in a fishermen channel accelerates adoption rates.

The accelerated adoption rates are due to the fact that the non-state actor is flooding the governed space with both broadcasting and narrowcasting cultural scripts, which accelerate both radicalization within an ideology and activation to utilize the template method to carry out contagion incidents.

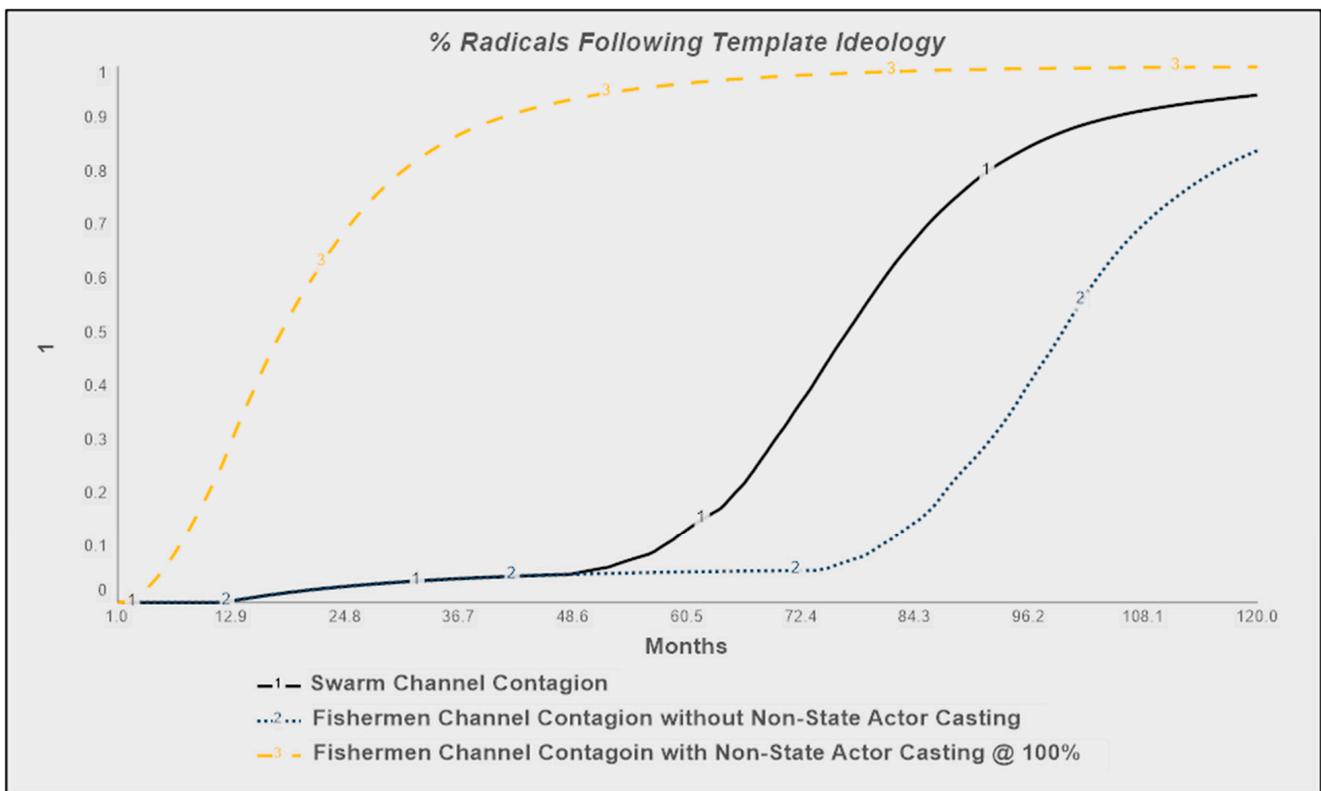


Figure 19. Radicals adopting template ideology by channel swarm vs. fishermen.

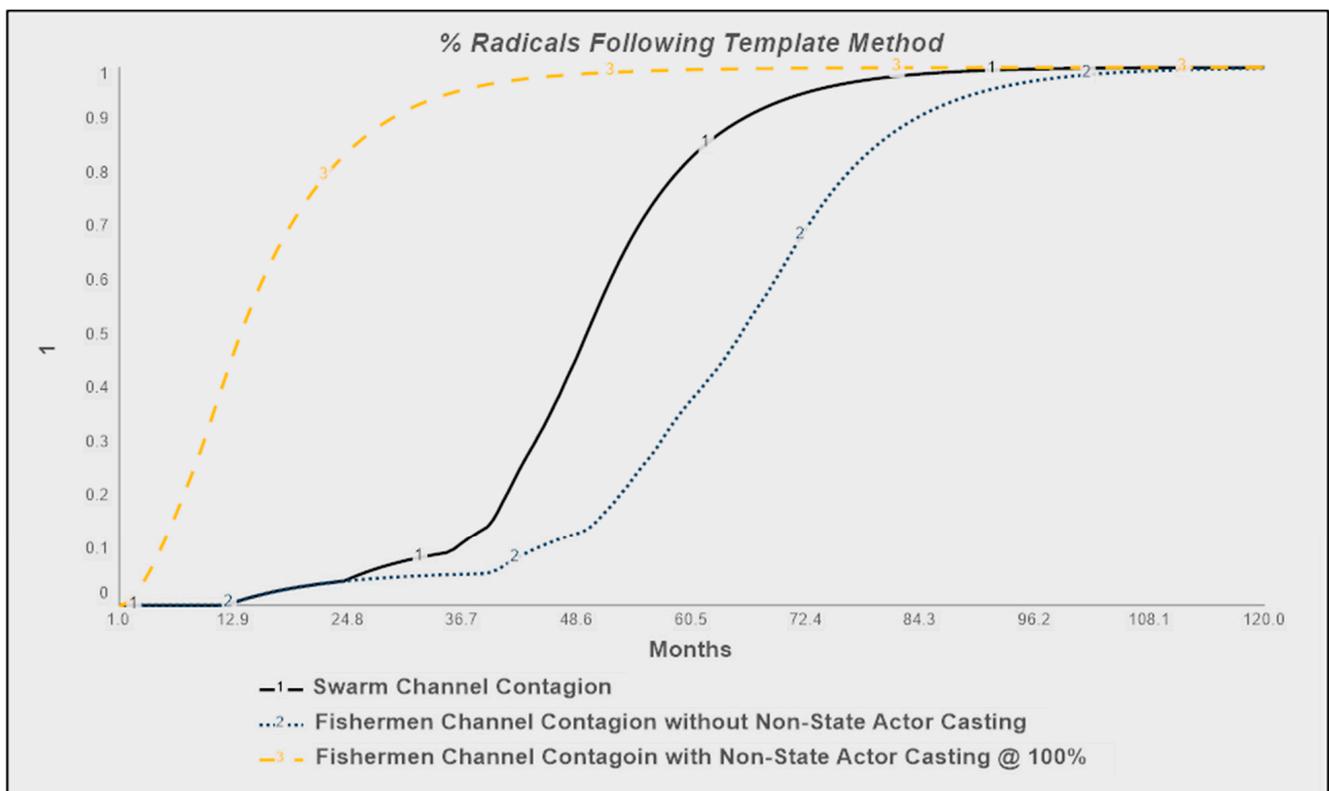


Figure 20. Activated adopting template method by channel swarm vs. fishermen.

We believe this demonstrates how the debate over root causes in the literature, between swarm and fishermen, could actually be a debate over manifestations within different channels. Where system contingencies are too weak to generate a contagion without non-state actor intervention, only violent ideologies supported by non-state actors operating from safe havens are sustainable. This is the manifestation most likely found when looking at smaller at-risk populations in the US and WEUR within the violent ideology of Salafi-takfiri. But when system contingencies are strong, all the ingredients necessary for contagion behavior are located in the governed space. For example, right- and left-wing extremism in the US and/or WEUR operate within large enough populations and do not require non-state actor support. Channel effects can lead to survivor bias in data collections. If data collection focuses on channels with low at-risk populations, fishermen manifestations will be more common. This can lead to a conclusion that violent terrorism is caused by non-state actors rather than a byproduct of the contingencies of a low at-risk population channel. Many violent ideologies may have been introduced into the channel with low contingent values. Still, only those supported by an outside source manifested into observable phenomena.

7.8. Proposition Strength & Policy Implications

Proposition strength aids future efforts to operationalize these findings into policies [45]. Policies incorporating strong propositions are useful for finding the means to eliminate contagions altogether. Moderate propositions should be embraced or mitigated based on how they weaken or strengthen a proposition, but will need to be combined into portfolios and supplement a strong proposition. Additionally, weak propositions, even if publicly popular, show less value in changing behavior.

8. Limitations

The limitations of our work unfold from the modeling process itself, namely, the data we used, the modeling boundaries we selected, the formulation approach to the simulation, and the nature of simulation experiments.

Simulations are limited by the data used to instantiate them. We inherit limitations found in the definition of terrorism from the GTD that extend into our data set. The GTD excludes several categories of acts that some might consider terrorism, including cyberterrorism, terrorism conducted by a criminal cartel motivated by profit, violence by the state, and violence within an existing conflict zone. Further, our data set from the GTD is limited to the US and WEUR 1995–2018. The definitional and data boundaries leave hundreds of thousands of incidents occurring in different times, geographic regions, or conflict zones out of scope.

Boundary selections in scoping the terror contagion simulation further limit our findings. Although affective violence is an important aspect of violent radicalization, we only modeled predatory mass violence. Likewise, both base runs and all experiments were limited to the initial growth of a violent ideology within an at-risk population among individuals. In reality, certain violent ideologies have intermingled with at-risk populations for decades or centuries. Also, at some point of growth, a terror contagion conceivably initiates the rise of organized violent non-state actors. This continuation of a lifecycle into more organized non-state actor violence leading to the creation of terrorism networks, insurgencies, or even emerging-state actors is outside the scope of this effort, but is studied elsewhere [49,50]. Finally, as this is an early-stage model, it will benefit from continued development, revision, and improvement.

Our selection of FSB over SIR frameworks may impact results. Additionally, although stochastic formulations for discrete activities exist in the field (see the IVEE Radicalization simulation discussed earlier) [12], we recognize that the use of this method to model terrorist incidents themselves is controversial in system dynamics. To bolster confidence that an observed result was not the outcome of a particular random seed fueling the RNG, we ran each non-equilibrium base run across 1000 permutations of different RNG seeds,

taking the mean and range of the results. This allowed us to use an ANOVA one-way test to evaluate statistical difference and power on contagion incidents between the base runs [51]. We also created an additional structure in the simulation activated by a switch in the loaded profile. A continuous formulation of Level 1 terror incidents bypasses all discrete and stochastic RNGs when the switch is active. This adheres to the conventional system dynamics method and allows side-by-side comparison between results obtained between two formulation types. However, this switch requires a different type of “seed event.” Instead of a singular “seed event” described in the literature and cases, a 12-month sustained wave of repeated contagion incidents occurs. We do not believe this representation is realistic with regards to the behavior observed in the historical record, which is why the default is selected as discrete.

However, as we continue to develop the model, we plan to explore revisions and enhancements to its formulation and structure. This could include improvements in structural equations, replacing the discrete Level 1 Incidents with either fully continuous formulation or a hybrid agent-based model, or approaching proposition analysis through structural uncertainty and leveraging an exploratory modeling approach. (For more on discrete vs. continuous formulation in Level 1 Incidents, see Sections B-3 Structure Assessment and B-7 Integration Errors in Validation & Confidence Building of the Supplementary Materials).

A large caveat is that these findings are generated from synthetic experiments conducted via simulation. The simulation is an early-stage model for understanding and uses a discrete stochastic formulation for resolving terror incidents. Parts of this model used methods controversial in the field of system dynamics. Moreover, the simulation will require further development and refinement to build confidence in its results.

9. Conclusions

This paper builds confidence in the terror contagion hypothesis that violent radicalization leading to mass violence terrorism operates within a system of social contagion. Within this system, the contingent values of key root cause propositions create channels within which violent ideologies and terrorist methods emerge.

We created a simulation capable of manifesting many plausible behavior modes of terrorism, including reference modes abstracted from historical data. With this simulation, we conducted experiments on sixteen testable propositions to identify contingent values that terror contagions would emerge, strengthen, or weaken.

We showed how six of these propositions combine to form a terror contagion. As a specific kind of social contagion, a terror contagion operates by spreading through cultural scripts, communicating a Template Ideology and Template Methods to at-risk populations susceptible to being violently radicalized. Among that population, those who use the template method of mass violence create sufficient media attention to spread cultural scripts and sustain social contagion. The threshold for these contingencies is low, but the absence of any of the six propositions eliminates the contagion.

Another key finding of our experiments into the terror contagion hypothesis may help to resolve the contentious historical swarm vs. fishermen debate. We demonstrated how the contingent values of the six propositions created channels downwards into the system of radicalization favoring swarm or fishermen manifestations. For example, a channel with a small at-risk population condition is not favorable for swarm behavior, as replication is too infrequent. However, an outside actor casting cultural scripts can strengthen weak contagions into stronger ones. We suggest that the swarm versus fishermen debate may have resulted from different researchers examining manifestations in different channels, some of which favored swarm and others of which favored fishermen; without realizing how channeling effects gave rise to these manifestations, they debated swarm or fishermen as the cause, rather than the byproducts, of the system.

We also believe there may be more channels and manifestations in the system of violent radicalization than swarm or fishermen alone. Future work could explore the large number of unsuccessful or low-fatality incidents to identify if there is a third type

of manifestation at work. This would build confidence in the general model through falsification, identifying the contingent values of template ideologies and methods that emerged but failed to spark terror contagions.

The simulation and the terror contagion hypothesis are in the early stages of confidence-building. We encourage other researchers to replicate or challenge our initial findings through simulation, either using the published terror contagion simulation or creating their own. These could include system dynamics simulations built on different (SIR), agent-based modeling, Markov chains, or hybrids. Such development will help to build confidence and refine the understanding of the terror contagion hypothesis.

The terror contagion hypothesis could benefit from behavioral ecology, microeconomics, and complex systems science outside of simulation approaches. What are the contingencies within which different violent ideologies might grow or decline? How are these contingencies, communicated by cultural scripts, selected for fitness, inherited, and evolved in adaptation? How does an increasing population of violently radicalized individuals emerge into recognizable non-state actor groups and proceed across a lifecycle of clandestine terror networks, insurgencies, and emerging state actors? Understanding these interactions and developing mathematical models explaining or forecasting fitness for these values is key to building further confidence in this work.

Our terror contagion hypothesis findings also provide a pathway for future research into other cultural-script, or so-called memetic, contagion phenomena. For example, future research should examine whether the terror contagion hypothesis and its propositions can inform how other forms of violence or non-violent yet toxic behaviors spread through groups or society via cultural scripts.

Finally, our results serve as a basis upon which to operationalize findings into policy analysis and recommendations. This begins an iterative approach to model refinement, confidence building, replication, calibration, and ultimately pilot programs to apply these concepts in practice. We hope these findings encourage other researchers to contribute to this effort.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/systems9040090/s1>. Supplementary Materials contains full model documentation including model structure diagrams, parameter description, parameterization specifics, and full runs for all analysis referenced in the article.

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