A relational event model approach to exploring the contagion of violence among gangs

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Abstract
Street gangs produce a system of norms, opportunity structures, and group processes conducive to violent exchanges. As a result, gang violence leads to enduring patterns of conflicts between rivals driven in part by expectations that any threats against one's group will lead to retaliation. While retaliation is a well-known mechanism that drives gang violence, it has limited potential to explain why violence appears to behave like a contagious disease. However, previous studies generally attempt to infer dynamic processes associated with the spread of violence using cross-sectional data or approximation of longitudinal analysis. In this study, we improve on prior work by considering the directionality and temporal order of gang violence incidents to reveal the emergence of local and higher order structural patterns of violence using the relational event framework. We show that while retaliation is indeed a critical driver of gang violence, other mechanisms explain how one violent incident can generate subsequent violence beyond the original dyad involved in a conflict. We find that gangs are receptive and adjust to recent conflicts, even when they are not directly involved in them. An analysis of the temporal dependence of gang conflicts highlights how group process and cultural expectations can facilitate the contagion of gang violence.

Keywords: Gangs, Violence, Relational events, Retaliation, Social Contagion, Social networks

Scholars have long argued that street gangs produce a system of norms, opportunity structures, and group processes conducive to violent exchanges (Klein, 1971; Short & Strodtbeck, 1965). More recently, research has examined the contagious nature of gang violence, revealing that the individuals most vulnerable to being violently victimized and engaging in violence are members of well-defined relatively small social networks (Brantingham et al., 2020; Green et al., 2017; Papachristos et al., 2013; Papachristos & Wildeman, 2013). Brantingham and colleagues (2020) specifically argued that these features likely explain their findings that gang violence is more contagious (i.e., clusters in space and time) than non-gang violence. The popularity of the contagion of violence hypothesis is directly tied to its potential policy implications to reduce gun violence (Abt, 2019; Brantingham, Carter, et al., 2021; Fagan et al., 2007; Slutkin et al., 2018). In fact, leveraging the group nature of much violence and the social networks that connect violent groups has been at the center of some the most encouraging innovations in policing and preventing violence (Braga et al., 2001; Braga & Weisburd, 2012; Gravel & Tita, 2015; Kennedy, 2009; Papachristos & Kirk, 2015; Roman et al., 2019).

The mechanisms that explain the social contagion of violence, however, are often not explicitly modeled in these analyses. Retaliation is often used as the prototypical incident to support the hypothesis that urban violence is contagious (Abt, 2019; Brantingham et al., 2020; J. Cohen & Tita, 1999; Loeffler & Flaxman, 2018; Loftin, 1986; Vilalta et al., 2021). Furthermore, many of these explanations focus on retaliation as a dyadic, reciprocal process: a geographically proximate individual or group initiates violence and the victimized individual or group subsequently seeks revenge. While such a process creates a vivid and useful image to explain how violence begets more violence, tit-for-tat retaliatory violence fails to explain how violence

spreads, both spatially and socially, beyond the initial neighborhood or dyad (Randle & Bichler, 2017).

Norms of retaliation play an important role in the social lives of young people in communities with high rates of violence (Anderson, 1999). This is particularly true in street gangs where violence and responses to violence play an important reputation building role (Decker, 1996; Papachristos, 2009; Vigil, 1988). Retaliation for actual or perceived slights is often the norm (Decker, 1996) and the status-enhancing nature of violence provides incentives both for individual involvement in violence (Gravel et al., 2018) and dominance contexts between groups (Nakamura et al., 2020; Papachristos, 2009). Decker (1996) argued that gang violence creates self-sustaining cycles of violence between groups through escalation in the severity of violence: a verbal threat leads to a fist-fight which leads to a shooting (see also Hughes et al., 2021).

Yet, two main weaknesses exist in gang studies limiting the identification of more complex mechanisms that are able explain the contagion of violence. First, research has generally focused on the space-time distribution of violent incidents to examine the contagion of violence (Brantingham et al., 2020; Loeffler & Flaxman, 2018), without much attention to the specific social exchanges through which violence supposedly spreads. The general assumption is that in urban environments, especially in communities where violence is common, spatial proximity is an adequate proxy for social relationships. Second, when more fine-grained analyses of violent exchanges between gangs is undertaken, the research often takes a cross-sectional approach (Bichler et al., 2020; Lewis & Papachristos, 2020; Nakamura et al., 2020; Papachristos, 2009), limiting the potential study of the inherent dynamic nature of contagion. That said, novel findings from these studies have revealed that supra-dyadic influences impact gang violence as

well as the directionality of violence between gangs (see also Bichler et al., 2020, 2021; Randle & Bichler, 2017).

In this study, we directly address the limitation of prior gang studies by considering the directionality and temporal order of incidents of gang violence. We take advantage of an underutilized tool to analyze gang violence: relational event models (REMs) (Butts, 2008). Our goal is to examine plausible mechanisms to explain patterns of violence between street gangs by moving beyond the simple dyadic retaliatory mechanism. REMs are particularly well-suited for this objective as they allow us to examine the specific social exchanges over time that are presumed to generate future violence, independent from opportunity generated through spatial proximity, and the stable history of rivalries between gangs. Furthermore, REMs allow us to follow the lead of recent scholars by studying supra-dyadic influences on violence (i.e., third parties) in a dynamic context. In doing so, we position the street gang as an actor whose actions are not solely influenced by their need for status, but that also reacts to the actions of other actors in their social environment, even when those actions do not directly involve them. Building from research on street gangs, inter-group conflict, and network theory, we use REMs to generate new insights and hypotheses that may explain why gang violence at the very least appears to be contagious.

The role of violence in street gangs

Inter-group conflict is a critical force that leads to formation and maintenance of street gangs (Brantingham et al., 2012; Decker, 1996; Decker & Van Winkle, 1996; Short & Strodtbeck, 1965; Thrasher, 1927; Vigil, 1988). As is the case in many different types of human groups (Festinger et al., 1950; Homans, 1950; Tajfel & Turner, 1979), the identification of rivals is critical to the *esprit de corps* of the group. The identification of an outgroup plays an important

role in the definition of the boundaries of a group (Papachristos, 2005; Reid & Valasik, 2020; Short & Strodtbeck, 1965; Tremblay et al., 2016).

Decker (1996) argued that violence played two important roles in the evolution of street gangs. First, he argued that violence builds group solidarity and delineates group boundaries. Despite popular conceptions in the media and in law enforcement circles, gangs rarely exhibit the kinds of rigid, hierarchical, military-like structures that would facilitate coordination in gang "wars." Instead, the consensus is that most gangs consist of loosely organized and connected subgroups, without stable leadership or even well-defined group boundaries (Bouchard & Spindler, 2010; Decker et al., 2013; Klein & Maxson, 2006; Ouellet et al., 2019a). However, while gang members tend to spend most of their time in small, loosely connected subgroups, research shows that gangs have the ability to—at least temporarily—come together as a cohesive group when faced with an external threat (Decker & Van Winkle, 1996; Hagedorn & Macon, 1998; Hughes & Short, 2005; Klein, 1971; Klein & Crawford, 1967; Short & Strodtbeck, 1965). Without a clear and present threat from other groups, Decker (1996) argued that gangs would struggle to recruit new members to counterbalance the high turnover of gang membership (e.g., Carson et al., 2013). Violence provides the gang a mechanism to behave as a group with similarly aligned interest in preserving the integrity of the group.

The other role violence plays in gangs is by generating normative expectations for violence. When faced with an outside threat—real or perceived—gang members become keenly aware of their dependence on one another for safety. Violence plays an important symbolic function in the gang and members expect one another to be ready to use violence against a rival. Decker (1996, p. 262) explains that an initial act of violence or the identification of a threat can lead to a "mobilizing event that pushes a ready and willing group beyond the constraints against

violence. Such events may include the deployment of gang members to protect or attack certain locations, to engage in actions in cars, or simply to act 'loco.'" Participation in the mobilizing events is expected of members and can strengthen the bonds between those participating. Even when mobilizing events do not translate into actual violence, they provide a source of excitement and individual members often derive social benefits (e.g. status, reputation) from their involvement and willingness to participate (Descormiers & Corrado, 2016). The stories of these events often take on a life of their own and contribute to the lasting collective myth of the gang created and maintained by both their members and others (Fleisher, 1998; Hughes & Short, 2014; Lauger, 2012; Papachristos, 2009; Vigil, 2020). Decker (1996) argues that these two functions—the collective and normative features of violence—work together to produce an incentive structure for future violence by reducing the individual barriers to involvement in serious violence. But what these studies have generally failed to consider are the factors related to why some gangs may choose to retaliate or not, and why certain gang characteristics, such as size, or turf location, may influence the spread of violence among the overall network of gangs.

Group competition and supra-dyadic processes

Individual acts of violence are likely to lead to more violence, especially in social contexts where violence is viewed as a legitimate means to resolve problems (Anderson, 1999), maintain order (Black, 1983), and provide youths a way to achieve status when conventional means are blocked (A. K. Cohen, 1955). Given that social status is meaningful only in relation to the status of other groups in one social sphere (e.g., Gravel et al., 2018), gangs have an incentive to be aware of the activities of other groups around them and be responsive to them in order to defend their place in the pecking order (Randle & Bichler, 2017). These contests for reputation

often take place over the protection of a territory (Brantingham et al., 2012, 2019; Radil et al., 2010; Tita & Radil, 2011; Valasik, 2018; Valasik et al., 2017).

Conflict between groups leads to the establishment of stable, long-lasting gang rivalry networks that become institutionalized through "regular patterns of conflict creat[ing] an organizational memory shaping a gang's subsequent violent behavior" (Papachristos et al., 2013, p. 421). Papachristos (2009) found that individual gang members' decisions on who to target with violence is considerably constrained by their groups' prior history of conflict and their groups' resulting position in the rivalry network. Furthermore, gangs are far more likely to engage in reciprocal violence when both groups' dominance over particular turf is contested, and when both groups have an extended history of violence (see also Brantingham et al., 2019; Nakamura et al., 2020; Taniguchi et al., 2011).

Lewis and Papachristos (2020) confirm that reciprocity tends to be the norm when it comes to gang violence in Chicago, but they also consider the importance of supra-dyadic patterns rarely discussed in gang scholarship. For instance, Lewis and Papachristos (2020) find that while two gangs are unlikely to be attacked by the same set of gangs, when they are, these gangs do not form alliances to fight their common foes but rather tend to also fight one another. Lewis and Papachristos (2020, p. 1853) conclude that there is very little evidence of hierarchical structuring in gang violence (e.g., lack of transitivity, absence of gangs who are victims only); gangs appear to "resist subordination by others and engage in ongoing, localized struggles to assert superiority."

Retaliation and other generative mechanism of gang violence

Most gang research typically talks about retaliation in very broad terms. For instance, Hughes and Short (2005, p. 48) define retaliation as "an action undertaken by one party to

avenge a previous attack or any other perceived or actual wrongdoing by the targeted party or a close associate."[1] Such an overly broad definition of retaliation likely obscures differences in the dynamics of different types of retaliatory violence. A more sophisticated understanding of retaliatory violence would be beneficial for practitioners and policymakers who are attempting to prevent gang violence (Bond et al., 2012; Brantingham, Tita, et al., 2021) and for a better understanding of the social contagion of violence (Loftin, 1986).

Jacobs (2004, p. 296) considers retaliation as the "obvious intersection between informal social control and moralism," drawing from work by Black (1983) and research on the subculture of violence (Anderson, 1999; Horowitz, 1983; Wolfgang & Ferracuti, 1967). In the context of street culture, where honor and toughness are commodities and cowardice is never a endorsed option, any affront should be reciprocated immediately. For instance, a gang member encountering a rival while trespassing on their territory, defacing their graffiti, or insulting them is likely to be met with immediate retribution. Retaliation of the sort is called "reflexive" and tends to involve a knee-jerk reaction by the aggrieved party, which is often precipitated by the presence of third parties (Cooney, 1998; Fagan et al., 2007; Valasik, 2018).

However, Jacobs (2004) argues that such an ideal scenario is not always available to the wronged party. In many cases, retaliation must be delayed out of necessity—until the violating party can be identified (called "deferred retaliation") or until competitive advantage can be secured (called "calculated retaliation"). Information on the streets is imperfect or inaccurate and it may be impossible to accurately identify the violating party. Furthermore, there may be situations where retaliation would be too costly given the competitive advantage one party holds over the other. In such cases, retaliation may never materialize because the opportunity never

[1] Although other gang researchers rarely have a formal definition for retaliation, their descriptions typically fall within the bounds of Hughes and Short's (2005) definition.

arises, or the wrong party is never identified. It may never materialize because one party is so much more dominant over the other that they are able to frame the violation as unworthy of their retaliatory efforts. Gould (2003) argued that conflict is much more likely to occur in symmetric relationships where social ranking is ambiguous. However, norms of retaliation typically dictates that any affront should receive a response, even if that response is imperfect.

Imperfect retaliation involves displacing violence towards a third party that was not involved in the original conflict. Jacobs and Wright (2006) argue that such violence is typically not the preferred outcome and will be used as a last resort. While not entirely satisfactory, these attacks play important symbolic and instrumental roles for the party engaging in them. To the extent that the victim is perceived by others as a worthy adversary, imperfect retaliation allows the party to regain status they perceived may have been lost as a result of the initial attack. The ability to engage in targeted attacks also sends a message to others about their willingness to retaliate, a step in achieving the instrumental goal of deterrence of future attacks by opponents who perceive cowardice and weakness (see Nakamura et al., 2020).

Reflexive, deferred, and calculated retaliation have limited potential for explaining contagion beyond the dyadic relationship. Any effective contagion mechanism must operate at a supra-dyadic level for violence between two actors to radiate to other actors. Imperfect retaliation provides such a mechanism (Bond et al., 2012; Jacobs & Wright, 2006). Not only does imperfect retaliation explain how a dyadic process spreads to others, but also provides an explanation for patterns of escalating violence. Leovy (2015, p. 206) highlights such a process among gang members in South Central Los Angeles: “A black assailant looking to kill a gang rival is looking, before anything else, for another black male … a presumed combatant, conscripted into a dismal existence ‘outside the law’ whether he wanted to be or not.” Since such

retaliatory violence involves unprovoked attacks, the impetuous for the victim to retaliate is even greater.

This research highlights two important aspects of retaliation that deserves further attention in the context of gang violence. First, while retaliation is often discussed as a dyadic process, how retaliation unfolds and spreads beyond the dyad depends very much on the actions and perceptions of other parties. The extent to which imperfect or delayed retaliation occurs in gang conflict is not well documented (Lewis & Papachristos, 2020). Second, whether retaliation occurs depends on both the history of conflicts between parties but also more immediate considerations, such as opportunities to retaliate, the strength of the other party, ongoing conflicts with other groups or even simply the group's ability to clearly identify the target for retaliation. In the context of street gang violence, geographic *and* social network proximity have been shown to play an independent role in predicting what happens next (Papachristos et al., 2013; Tita & Radil, 2011).

Gang violence and the relational event framework

While both Papachristos (2009) and Lewis and Papachristos (2020) were interested in unlocking the dynamics of gang violence, they rely on the analysis of aggregated relationships over several years, a strategy increasingly used to approximate longitudinal network analysis of criminal networks (Bichler et al., 2017; Bright et al., 2019; Ouellet et al., 2019b; Randle & Bichler, 2017). Lewis and Papachristos (2020) find that network effects were highly inconsistent compared to the large aggregated network when they analysed smaller time slices of their network. This finding highlights important limitations of aggregating relationships to assess the dynamics of violence and other social networks (Mulder & Leenders, 2019). Violent conflicts can lead to lasting relationships like rivalries, but other incidents may be driven purely by

situational factors with conflicts dying out as soon as these factors change. Furthermore, each incident occurs at a discrete point in time and the analysis of the influence of their timing and relative order is at the core of most explanations of gang conflicts. The use of aggregated networks of violent exchanges is likely to mask important temporal dynamics (see Faust & Tita, 2019 for a critique of this approach). In this study, we improve on prior work by considering the directionality and temporal order of gang violence incidents to reveal the emergence of local and higher order structural patterns of violence using the relational event framework.

The relational event framework is a generalized analytical approach that is able to include "a wide assortment of cognitive, behavioral, and social/contextual processes" to forecast future dynamic social behaviors (Butts, 2008, p. 158; Butts & Marcum, 2017). The principal element is the *relational event* (i.e., gang violence) which is a discrete even performed by one social actor (i.e., gang member), the sender, and directed towards another social actor, the receiver. According to Butts and Marcum (2017) the social interaction being examined (i.e., the relational event) becomes the unit of analysis. A REM requires a series of time ordered events which comprises an event history that documents the sequence of social actions that transpire between a set of senders and a set of receivers over a delineated time period (Butts, 2008; Butts & Marcum, 2017). REMs rely upon a simplifying assumption that each potential event (i.e., gang violence) is conditionally independent and the potential event's *hazard*, the propensity for a particular social action to transpire, remains constant while accounting for the prior history of events (Butts, 2008, 2017). Observing social actions that transpired in addition to social actions that did not transpire, but could have, REMs seek to identify the propensities for all possible events to occur (Butts & Marcum, 2017).

The relational event framework revolves around discrete social actions between actors in a system and allows the modeling of complex social, contextual, and behavioral processes responsible for these actions (Butts, 2008). The theoretical foundation of REM rests on the notion that, while different perspectives exist regarding the mechanisms that drive social action, most perspectives intersect around a "'core' notion of action per se as a directed behavioral event, potentially contingent on past history" (Butts, 2008, p.156).

Methods

Data

This study relies on data maintained by the Los Angeles Police Department's Hollenbeck Community Policing Area and were originally collected as a part of a project aimed at reducing gun violence committed by gangs in the Boyle Heights neighborhood of Los Angeles (Tita et al., 2003). The data include all known gang-related violent crimes from May 2000 through December 2002. During the research period Hollenbeck experienced 1,190 "gang-related" violent crimes, in which the offender, victim, or both were known to be associated with a gang. In 419 of these incidents, gang affiliation was known for both the victim and the offender. Twenty-six of these events involved gangs that whose territory was not in the study area. Thus, the final data used for our analysis are 393 violent interactions between 33 criminally active Hollenbeck gangs. These interactions include simple and aggravated assault, assault with a deadly weapon, homicide and attempted homicide, robbery, kidnapping, and firing a weapon into an inhabited dwelling or vehicle. On average, gangs directed 13.55 attacks to other gangs and were attacked 12.28 times over the study period.

Covariates

Control variables

Public housing. Public housing complexes in Hollenbeck were mapped to ascertain if any gang territory overlapped with these communities. Griffiths and Tita (2009) argue that residents in LA's public housing communities have historically been socially isolated from other communities, leading to social networks that are rather confined to these communities. Therefore, it is expected that gangs residing in a public housing community may be more likely to be involved in violence. Seven of the 33 Hollenbeck gangs (21.2%) had territories overlapping with public housing communities.

Rivalry. The rivalries between the gangs of Hollenbeck were identified by a survey provided to both LAPD and gang members (see further Tita et al., 2003; Tita & Radil, 2011). All gangs have at least one rival, with the number of rivals ranging of one to ten and gangs have 5.79 rivals on average (s.d.=2.45).

Territorial distance. The boundaries and locations of gang territorial claims were identified and mapped through collaboration with detectives and patrol officers in LAPD's Hollenbeck gang unit and Los Angeles County probation officers, who were assigned solely with Hollenbeck gang members. These gang experts were provided with detailed maps of Hollenbeck and asked to draw the boundaries of each gang's turf. This information was later digitized in ArcGIS, allowing us to ascertain which gangs were "neighboring" (directly adjacent to) other gangs. Additionally, this information is used to account for propinquity and control for the distance between each gangs' territory (see Tita et al., 2003).

Bonacich Power in rivalry network

We include *Bonacich power* (Bonacich, 1987) of gangs in the rivalry network. Bonacich power is similar to eigenvector centrality. It is defined as the sum of the number of connections of node has weighted by the degree centralities their alters. Bonacich power allows us to specify

a parameter β for the size and direction of the weight given to other nodes' centralities. We set the value of β to be the negative reciprocal of the largest eigenvalue of the rivalry adjacency matrix. Setting a negative value of β means that Clover who is connected to gangs with fewer rivals will have a greater Bonacich power score than Hazard who is connected to gangs with many rivals, despite Clover and Hazard having the same number of rivals.

Negative Bonacich power reflects a measure of status derived from the lack of alternative paths of ego's alters have in their own network and these alters' greater dependence on ego. Bonacich's (1987) motivation for creating this new measure was to account for the fact that degree centrality in exchange networks does not necessarily correlate with success. Cook et al. (1983) found that people with many connections to potential trading partners who themselves had many trading partners reduced that person's ability to bargain as, in this context, it is advantageous to be connected to people with fewer trading options. In the context of a rivalry network, high Bonacich power may reflect the local dominance of a gang. Under such a scenario, the dominance of a gang may have led rival groups to dedicate all their efforts towards the dominant gang, and less towards other potential rival. In this case, we would expect high Bonacich power to be predictive of greater aggression.

Gang size

Gang size as measured bywas measured membership was collected using the CalGang database as of September 1, 2003. Determining membership size using databases remain a contentious topic for a variety reasons including high turnover rates, failure to remove non-active/deceased members, and the misidentification of assocaites (e.g., Densley & Pyrooz, 2020; Huff & Barrows, 2015). Though such databases might not provide precise numbers of members, they are useful in estimating membership. Therefore, we categorize gangs using size estimate

quartiles as cut points. Small gangs (21.2%) refer to groups with less than 60 members; Medium gangs (33.3%) have between 80 and 130 members; Large gangs (18.2%) have between 150 and 250 members; and very large gangs (27.3%) have more than 300 members.

Model parameters

Table 2 summarizes the main model statistics which refers to different temporal patterns of exchanges between gangs in Hollenbeck. These statistics encode past exchange patterns to predict the rate of specific future exchanges. We consider four broad categories of statistics in our model. Of particular interest to our current analyses are three statistics that represent different forms of retaliation. *Delayed retaliation* examines whether gangs have a tendency to attack gangs who most recently attacked them. *Immediate retaliation* is a much more strict definition of retaliation which captures whether retaliation will occur so quickly after an attack that the sequence of event is not interrupted by any other gang conflict in Hollenbeck. *Imperfect retaliation* refers to situations where a victimized gang immediately launches an attack but the target is different than their attacker.

We also include a set of statistics that represents overall and recency inertia in a gang's choice of target. Specifically, we examine whether gangs continue to attack their most common previous victim (*Target history*) and whether gangs continue to attack their most recent victims (*Target recency*). We include a statistic that measures *Cyclical violence* which examines whether a focal gang's rate of attack on a target depends on how often that target has attacked a gang that targeted the focal gang (i.e., is the enemy of my enemies also my enemy). Finally, we include a statistic that captures the tendency of gangs to engage in several consecutive attacks against different gangs (*Violent spree*). We used the R package *relevant* (Butts, 2015) and fitted an exact time model using maximum likelihood.

<INSERT TABLE 1>

Results

Figure 1 shows the aggregated violence over the study period. Node sizes represent the sizes of the gang, the color of the edges represent the intensity (e.g. frequency) of the violence directed. The nodes are positioned relative to the geographic position of their territories. Dashed lines represent violence between groups who are not rivals, and full lines represent violence involving rivals. Figure 1 shows the importance of proximity for gang violence as most violent ties remain relatively constrained in the local periphery of each gangs. The network also highlights the importance of rivalries. While some violence occurs between non-rivals, such violence is not very frequent, and the most intense violence occurs between rivals. Of all incidents, 88.3% involved rivals.

<INSERT FIGURE 1>

REM

<INSERT TABLE 2>

Gang controls

The results of the REM are presented in Table 2. First, gang violence occurs far more frequently between rivals ($\beta = 1.968$, $p < .001$). The rate of violence between rivals was more than 7 times that of violence between non-rivals, a finding consistent with most of the literature on the topic (Brantingham et al., 2012; Papachristos et al., 2013; Radil et al., 2010). Second, gang violence is a function of the spatial proximity of gang territories ($\beta = -0.261$, $p < .001$); for every 1 km increase between gang territories, the rate of violence between gangs decreases by 23%. This finding is again consistently with the literature (Papachristos et al., 2013; Valasik,

2018). Third, gangs who claim turf in public housing initiate attacks on other gangs at a higher rate ($\beta = 0.246$, $p < .05$), but are victimized at a lower rate than non-public housing gangs ($\beta = -0.311$, $p < .05$). It appears that public housing communities provide gangs with a competitive advantage both in terms of their ability to attack and to avoid victimization (Barton et al., 2021; Griffiths & Tita, 2009). Many public housing projects (see e.g., map of Ramona Gardens, Figure 2) are built as clusters of buildings interconnected by walkways accessed by only one or two streets. This design leaves very few entry and exit points into the community making it easy to identify intruders from gangs who do not reside in the public housing community (e.g., Griffiths & Tita, 2009; Lasley, 1998). Gangs in those communities may hold a substantial advantage over potential attackers who venture in those communities. Even when outside gangs enter these communities with the intent to attack the resident gang, they may be easily spotted, turning the hunter into a prey. This would explain why public housing gangs both attack at a higher rate and are victimized as a lower rate.

<INSERT FIGURE 2>

Gang size, status, and gang violence

On one hand, gang size could simply be interpreted as a gang's capacity to attack and be attacked; more members are available to attack other gangs and other gangs have more members to attack. In this context, there should be a positive relationship between size and both attacks and victimization. On the other hand, gang size can be thought of as a visible indicator of strength and power to rivals and other gangs. In this context, the relationship between size and violence, is more difficult to predict and whether the effect is the same for attacking and being victimized is unclear (Brantingham et al., 2019). The size of the largest gangs may provide

protection against attacks by their smaller counterparts. At the same time, attacking large gangs could be an efficient way for small gangs to signal to others that they should not be taken lightly.

Our finding suggests that small gangs are victimized at a lower rate than larger gangs, but they attack other gangs at a rate similar to medium and very large gangs. Only large gangs—the second largest group—have a significantly higher rate of attacks compared to small gangs: Large gangs attack other gangs at a rate 72% greater than small gangs. Small gangs, it appears, do not seem to be hindered in their ability to attack, which is surprising considering that very large gangs can have a membership 10 times the size of small gangs, and yet, they engage in a similar rate of attacks. This finding, combined with the fact that large gangs appear to have a higher rate of attacks compared to small and medium gangs, highlights that gang size has a complex relationship with a group's ability or willingness to attack. Small gangs also appear to be attacked less often than gangs of any other size. Very large gangs are victimized at more than twice the rate of small gangs.

Small gangs may simply be compensating for their lack of effectives by attempting to build a particularly violent reputation. An alternative explanation may be due to the differential status-enhancing value of attacking gangs outside their size group. Gangs may be able to accrue more status if they can attack larger, more established gangs. The smallest groups in Hollenbeck have no choice but to either attack gangs of similar or larger gangs. Small gangs may be in adoubly advantageous position. Given their position in the size hierarchy, small gangs have many potential high-value targets to choose from, whereas the largest gangs can only attack gangs of their own size or below. If the same principle applies for all gangs, then, the largest gangs may not receive much status from attacking or retaliating against much smaller gangs. Therefore, small gangs may be in a position to attack others with more impunity, which would

explain both small gangs' low rate of victimization. In fact, given their limited upward mobility, the largest gangs may not only have the luxury to ignore attacks from smaller groups, but rationalizing that attacking small groups is not "worth it" may in fact be a way for larger gangs to continue to assert their dominance in the community.

Consistent with this interpretation is the exception we observe with large gangs who are both more likely to attack and be attacked comparedto small gangs. These groups may be in a no-mans-land of status-building behavior where they do not necessarily command the same respect that the very large gangs enjoy among the smaller groups, but are large enough to be taken seriously by the very large gangs. Not being on top of the food chain means having to worry about attacks from the largest gangs, and making sure to keep those of similar status at bay. This situation may explain why they are both more likely to attack and be attacked compared to other groups.

It is also possible that the underlying network structure of these larger groups play an important role is explaining this finding. Very large gangs can only be sustained if they are divided in smaller, often age-graded subgroups or cliques (Klein & Maxson, 2006). As a result, these gangs may lack the ability to effectively coordinate attacks or responses. Ironically, their size may make them more vulnerable to attacks as these groups are likely to spend more of their times in small groups rather than gather as large groups. For smaller gangs, this is a win-win situation as these isolated small groups may be easier to attack but the reputation gains are evaluated in terms of the identity of the gang that subgroup belonged to. Large gangs—between 100 and 200 members may be more likely to maintain dense structure with a core-periphery structure. These groups' structure may grant them a greater ability to mobilize their members against a threat from another group, and their size may allow them to execute these attacks more

effectively. On the other hand, large core-periphery structures may leave a large number of members more vulnerable to attacks by other gangs as they lack the protection of the core membership (Morselli, 2009).

Bonacich power in rivalry networks

Findings relating to a gang's position in the rivalry network highlights the importance of supra-dyadic processes for gang violence. Bonacich power is positively associated with involvement in violence ($\beta = 0.283$, $p < .05$), but negatively associated ($\beta = -0.295$, $p < .05$) with being attacked. In the present context, high Bonacich power indicates gangs with many rivals who have few rivals themselves. Gangs with many rivals who themselves have few opportunities to build their status may be able to take advantage of their position to increase their own status by attacking several different groups. In doing so, they may send their rivals strong signals that they will not hesitate to retaliate if they choose to attack.

<INSERT FIGURE 3>

Alternatively, this could suggest that gangs may be attempting to keep in check others who have historically focused their violence towards them. Gangs are typically aware of ongoing rivalries that exist between other groups (Nakamura et al., 2020), and may use that information to gauge when to pay more or less attention to rivals. However, doing so is only possible when the reference gangs only have a few rivals. For instance, consider the rivalries involving Clover, Highland Park, and Avenues in Figure 3. In such a configuration, Clover may be in a better position to assess whether Highland Park and Avenues can be ignored without repercussion, since Clover only needs to monitor the intensity of the conflict between those gangs. Clover may either be free to focus their energy on conflicts with other rivals, or may use the opportunity to attack either Highland Park or Avenues, in the fog of their war against one another, with less

chance of retaliation. Highland Park and the Avenues face a greater challenge with regards to keep track of the many rivalries Clover has, which may make it difficult for them to predict what Clover will do next.

Cyclical violence

There is a relatively small but significant effect of cyclical violence in the model ($\beta = 0.095$, $p < .01$). This effect indicates a tendency for violence to cluster among small groups of gangs. Formally, cyclical violence in this context indicates the number of incoming 2-paths from Gang A to Gang B, increases the frequency of future violence directed to Gang A by Gang B by almost 10%. In Figure 3, consider the incoming two-paths between Hazard and 18th Street (Hazard→Rose Hills→18th Street, and Hazard→Happy Valley→18th Street); as the number of gangs Hazard attacks who have previously attacked 18th street increases, the frequency of attacks 18th street will direct toward Hazard—the enemy of their enemies—increases by 10%. In gang violence, it appears that all else being equal, the enemy of my enemy is my enemy, a finding consistent with research on other gangs in the Los Angeles area (Nakamura et al., 2020) but not with findings from Chicago gangs (Lewis & Papachristos, 2020).

A potential explanation for this finding is that gangs may view attacks by socially distant gangs (i.e., spatially or socially) on gangs more familiar or closer to them—even if they are rivals or past foes—as unacceptable or threatening (Gravel et al., 2018). A gang from a different neighborhood attacking another's rival from their neighborhood, or a newcomer attacking other older, well-established gangs could trigger an attack from a third party. For instance, returning to Figure 3, we can see that 18th street is closer to Happy Valley and Rose Hills in the rivalry network (and spatially) than they are to Hazard. The third party gang (18th Street in Figure 3) launching an attack closing the cyclical triad (18th Street→ Hazard) need not be seen as the result

of an alliance between foes, though this is possible. Rather, a more simple explanation is that a gang may attempt to assert their dominance against an encroaching gang by preemptively attacking them.

Inertia and recency effects

We find a strong effect of target history ($\beta = 1.204$, $p < .001$) in the model. For every 10% increase in the percentage of past violence received by Gang A, attributed to Gang B, the frequency of future violence from gang A to gang B increase by 12.8%. In the context of this model, this effect is consistent with the notion that gangs have a tendency to reignite conflict with their preferred targets regardless of other, newer conflicts that may emerge. This effect is emblematic of the enduring nature of conflicts between gangs that sometime become engrained in the gang's DNA through mythmaking and story-telling (Decker, 1996; Fleisher, 1998; Lauger, 2012), leading to the institutionalization of gang conflict (Papachristos, 2009). Furthermore, it may be that gangs prefer to attack gangs they have been successful against in the past; launching an attack with an unfamiliar target may carry with it more uncertainty.

Our model also highlights the importance of target recency as today's target is far more likely to be the tomorrow's target ($\beta = 1.109$, $p < .001$). Consider Gang A's past targets ranked beginning with the most recent as Gang 1, Gang 2, and Gang 3. Holding everything else constant, we find that Gang A's attacks on Gang 1 in the future are 74% more frequent than attacks on Gang 2, and 109% more frequent than attacks on Gang 3.

Retaliation

There are two main ways we capture retaliatory violence in our model. First, we consider how likely a gang is to respond to attacks based on the recency of attacks. Second, we consider whether retaliation is immediate, meaning that if Gang A attacks Gang B, the very next incident

involving any gangs in Hollenbeck would involve Gang B attacking Gang A. The latter is a fairly strict definition of retaliation considering that the median time between any two incidents during the study period was about 28 hours and 90% of events were followed by another within a little over 5 days.

Gangs attack (retaliate against) the most recent gangs that have attacked them at a higher rate ($\beta = 0.778$, $p < .001$). If the gangs who attacked Gang A are ranked beginning with the most recent as Gang 1, Gang 2, and Gang 3, holding everything else constant, Gang A will retaliate against Gang 1 47.5% more frequently than Gang 2, and 68% more frequently than Gang 3. It is important to note that this effect is above and beyond the effect of inertia and recency of targets on future choices of targets, as well as the influence of long-term rivalry between groups. Cycles of retaliation often associated with gang violence are not simply an artifact of gangs having the same consistent set of rivals and target. Long-term patterns of violence definitely play a large role in predicting future violence, but gangs are also attentive and react to more immediate threats and challenges.

However, gangs' reaction time to challenges is not immediate. We do not find significant evidence that retaliation is immediate ($\beta = 0.513$, $p = .116$). Considering how frequent conflicts between gangs in Hollenbeck occur, it is highly likely that the sequence of event A → B , B → A, will be interrupted by another incident. In that sense, using this parameter to evaluate the swiftness of a gang's response to an attack may provide a limited answer to that question. In fact, given that at any point in time, 1,056 different directed violent dyads can occur (i.e. 33 x(33-1)), the fact that the coefficient for immediate retaliation has a p-value of 0.11 indicates the importance of retaliation, even with such a strict criteria for retaliation. However, this finding also reinforces the importance of supra-dyadic factors to predict gang violence. Conflict between

any two gangs is not simply dependent on either groups' decision and/or ability to attack or respond to the other, but also depends on the decisions of other groups to get involved with either of the gangs in conflict. This finding is also consistent with research highlighting the role information asymmetry play in retaliation (e.g. Jacobs, 2004). Gangs may not always be able to clearly identify their attacker, or may not have the strength and sources to retaliate against some groups, which may delay or altogether negate retaliation.

We do not find statically significant evidence that gangs under attack will immediately displace their aggression towards another group ($\beta = 0.265$, $p = .372$), which could be an outcome of either mistaken identity or an attempt to recoup reputation by attacking a more manageable target than the gang who originally attack them. Again, these mechanisms may very well be at play at later times, but if they do happen in Hollenbeck, they happen after other violence between other groups has transpired.

Violent sprees

Our model suggests that gangs in Hollenbeck frequently attacked different gangs in immediate succession ($\beta = 0.604$, $p < .05$). Holding all else constant, Gang A is 82.9% more likely to immediately follow an attack on Gang B with a second attack on a different Gang C. Prior research contends that violence plays an important role in building, maintaining, and modifying gang cohesion (e.g. Decker, 1996; Klein, 1971). We suggest that the act of engaging in violence may temporarily increase gang cohesion and reduce the barriers for more acts of violence to be committed.

Goodness of fit

To assess the goodness of fit of our model we checked how well it was able to predict the observed gang attacks. For this purpose, we computed the relative rank of each observed dyadic

attack by ranking all dyads from most plausible (relative rank of 1) to least plausible (relative rank of 1/1056=0.001, as there are 1,056 dyads at risk) according to the fitted model. The relative ranks of all 393 events are plotted in Figure 4. The figure shows that almost all relative ranks are very close to 1 (the median relative rank was equal to 0.980). Overall, this illustrates a very good fit of our model. Furthermore, since the events are present in order of occurrence and there is no clear evidence of clustering of low ranking events, we can conclude that the performance of the model is homogenous over time.

<INSERT FIGURE 4>

Next, we investigated to what degree each predictor variable contributes to the variability of the rates of the gang attacks. To see this, we multiplied the values of each predictor variable for all observed dyads with its respective coefficient. Predictors having a distribution with a large variability are more important to explain the observed variability which gangs that are involved in the attacks and with what rate. Figure 5 shows the resulting distribution for each predictor. Predictors such as inertia (FrRecSnd), Bonacich power (attack & victim), or the distance between territories explain the variability in the observed attack more than whether the turf of a gang is in public housing (attacker & victim), and much more than the three participation shifts (immediate retaliation, imperfect retaliation and violent spree).

<INSERT FIGURE 5>

Limitations

While the current study advances research on the dynamics of gang violence, several limitations need to be acknowledged. The data employed from this study relies on police records and reporting bias may exist as not all violent interactions between gangs may be reported. That said, specialized police units, such as homicide and gang units, dedicate more time and effort in

investigating violent or gang-related crime (Katz & Webb, 2006; Pizarro et al., 2020). Prior studies have affirmed that gang data are reliably collected by law enforcement (Decker & Pyrooz, 2010; Katz et al., 2000). In this study, the thoroughness of investigating gang-related violence is crucial, since the analyses require reliable data on gang affiliations of both the suspect and the victim. This study also focuses on a local jurisdiction within the city of Los Angeles to improve generalizability with other municipalities that are closer in size (approximate 180,000 residents). However, the results may be restricted to urban areas that are more similar to Hollenbeck. Relatedly, Hollenbeck's gangs are demographically homogeneous, being mostly of Mexican American descent, and considered to be "traditional" in nature, with strong territorial dispositions and intergenerational linkages (Klein & Maxson, 2006; Tita et al., 2003; Vigil, 1988). As such, the findings from the current study may be limited to regions where only "traditional" gangs are more prevalent.

We also point out that we do not use in the analyses events that do not have named gangs on both sides of a dyad. Thus, there are many events that are known or suspected to be gang-related, but cannot be attributed to a specific dyad. With additional information to properly place these events, the detected statistical patterns might change substantially.

Discussion

From the outside looking in, gangs appear to operate in a highly chaotic environment populated with unpredictable people who seem to have a complete disregard for the long-term consequences of their actions. The news media often refer to these behaviors as acts of senseless violence. Yet, outsiders often fail to understand just how valuable a reputation is to gang members; How others perceive them may very well save or end their lives someday. There is

nothing “senseless” about gang violence and with the proper data and methodology, we can see the method to the madness.

Scholars and outside observers both recognize at least one of the important sources of order in gang violence: Retaliation. As important as retaliation is to our understanding of gang violence, prior research has generally failed to consider the temporal structure of retaliation and the broader social context in which it occurs. Research on the contagion of violence in street gangs suffer from similar limitations hindering our ability to understand mechanisms through which violence spreads beyond the dyads and neighborhoods where it occurs.

In this paper, we introduce a methodology to the field of gang research that can overcome previous limitations and produce findings that highlight other plausible mechanisms for the social contagion of gang violence. We conceived of gang conflicts as relational events, where inter-gang violence is contingent not only on the characteristics of the groups involved but also on both the recent and distant history of conflicts involving all gangs in a community. Gang scholars have long argued for approaches that consider both group processes and micro-level interactions between gangs (Decker et al., 2013; Short, 1985, 1998).

We show that retaliation—as Jacobs (2004) points out— likely comes in many forms and occurs above and beyond the effect of historical rivalries, spatial proximity, and gangs’ general tendency to consistently attack the same groups. While retaliation is not always swift and immediate, gangs do seem to prioritize the last gang to attack as a future target. This finding is important because it shows that gangs are actually responsive to their environment, rather than simply following tradition and mechanistically attacking the same rivals or groups over and over.

However, inertia in target choices is a powerful force in gang violence which is consistent with the notion that gangs do not always respond to *actual* threats but to *perceived*

threats that may arise from minor activities of a rival group interpreted as signs of disrespect (Decker, 1996; Decker & Van Winkle, 1996). While a gang may claim an attack to be retaliation for some *perceived* slight, the targeted gang may fail to recognize what motivated the attack, interpreting it as an unprovoked challenge to their status. It is not uncommon for gang members to claim at once that they will only commit violence if they are provoked and point out that other gangs attack them for no reason (Aspholm, 2020; Decker & Van Winkle, 1996). In a context where many attacks are perceived as unprovoked by the victim and retaliatory by the perpetrator, a single initial attack can produce self-fulfilling cycles of retaliatory violence between dyads. The explanatory power of inertia in target choices and the lasting impact of rivalries in our model suggests that retaliation may be more a rationalization for violence than a driving force.

If violence is a currency in the gang status economy, it is clear that not all groups have an equal ability to participate in that economy. Generally, our models shows that some groups occupy social (Bonacich Power) and spatial positions (e.g. Public housing communities) that place them in advantageous position to fight other gangs, while avoiding victimization. Gang size appears to play an important role in gang's ability to engage in violence, but like previous studies before us (e.g. Brantingham et al., 2019), we show that the relationship between size, status, and violence is complex. Gang size may be related to violence through two separate mechanisms. The first—the opportunity mechanism—simply places size as an indicator of the number of potential attackers and victims a gang has. This mechanism predicts a somewhat linear and positive relationship between size and the frequency of both attacking and victimization. The second—the status mechanism—makes size a proxy for status, or how established and entrenched a gang is in the area. Predicting the effect of size on the frequency of

attacking and victimization using this mechanism is not as straightforward because it depends on *who* is attacking and *who* is being attacked, implying different relationships for either.

When it comes to victimization, small gangs seem to be the only gang following the anticipated trend of being victimized the least. Beyond small gangs, the difference in the rate of victimization only increases by small increments as we move from one size category to the next. When it comes to attacking, the effect of size is more puzzling, with small gangs essentially attacking other gangs at a similar frequency as medium and very large gangs, but at a lower frequency compared to large gangs. In this case, the divide in advantage occurs sharply between medium and large gangs, with very large gangs having a slightly lower frequency of attacking than large gangs. What seems to be clear is that gang size is not a deterrent against attacks. That is, having a larger membership does not provide a clear advantage in attacking others.

While a gang's membership may be in the hundreds, these groups rarely, if ever, congregate together in large numbers and most everyday routines of gang members involve spending times in pairs or small cliques. In fact, it may be that larger gangs are *preferred* targets for smaller gangs. Small gangs may still gain the symbolic rewards of attacking larger, more established gangs, even if in effect they are attacking cliques that are much closer (or smaller) in size than they are. A similar logic would dictate that attacking much smaller gangs may not be worth the effort. This results in a system where the smallest gangs have many more opportunities to attack groups larger than them, and have few groups who would gain much from attacking them. The reverse is true for the largest gangs in such a system. As a gang's size moves towards the middle of this continuum, these groups seeking to attack the largest gangs do not receive the benefit of being ignored in the same way that the smallest groups do. While this interpretation is based on the patterns of results we observe in our study, future studies should examine at a more

fine-grained level whether this observation holds. It is also necessary for future research to examine how gangs of different sizes interact with one another (Brantingham et al. 2019).

Our findings suggest several plausible mechanisms to explain the contagion of gang violence beyond retaliation. First, we found a tendency for cyclic closure in gang violence. The notion that gangs may attack the enemy of their enemies may reflect a similar process to what Urbanik (2018) called the "neighborhood master status". Urbanik observed that the emergence of a rival viewed as legitimately belonging to the same neighborhood may not be met with the same violence as an outside group would. In this context, gangs may not appreciate *any* type of encroachment what they claim to be theirs, and this may extend to rivals as well. That is not to say that gangs are necessarily eager to defend their rivals, but rather, gangs may view an attack on socially close others (e.g. rivals from the same neighborhood) as a potential threat to their group as well. Cyclic violence therefore produces one pathway for violence to spread beyond the dyad of originally conflicting gangs and potentially beyond the neighborhood.

Second, we observe a tendency to attack different gangs in quick succession. Gang scholars have long observed the cohesion-inducing effect of violence in street gangs (Klein & Crawford, 1967; Papachristos, 2013). Another potential contagion mechanism may come from internal processes at play in street gangs. Decker (1996) suggested that gang violence became contagious through a process of escalation, but it is possible that an initial act of violence may galvanize a group to escalate other conflicts as well.

To draw from the viral analogy, retaliation can be thought of as operating through the contagion mechanisms of blood-borne diseases, where direct contact is required for transmission. Group processes may allow violence to behave more like airborne diseases, as initial acts of violence may trigger other violence by individuals and groups who were close to, but not directly

involved in, the initial conflict. In this context, conflicts spreading beyond the dyad to a uninvolved third party may be particularly "virulent" as the targeted third party may be more likely to see such attacks as unprovoked and have more incentives to retaliate.

Figure 1. Aggregated violence between 2000 and 2002

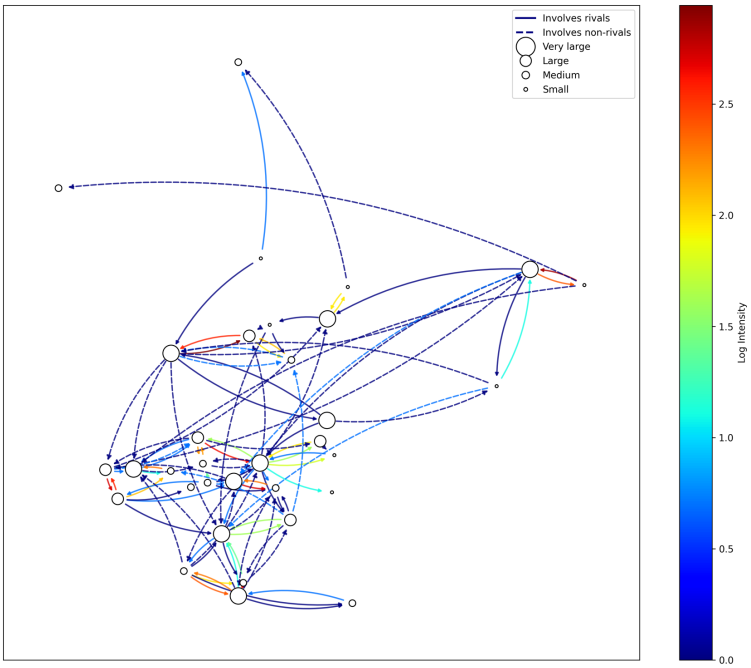
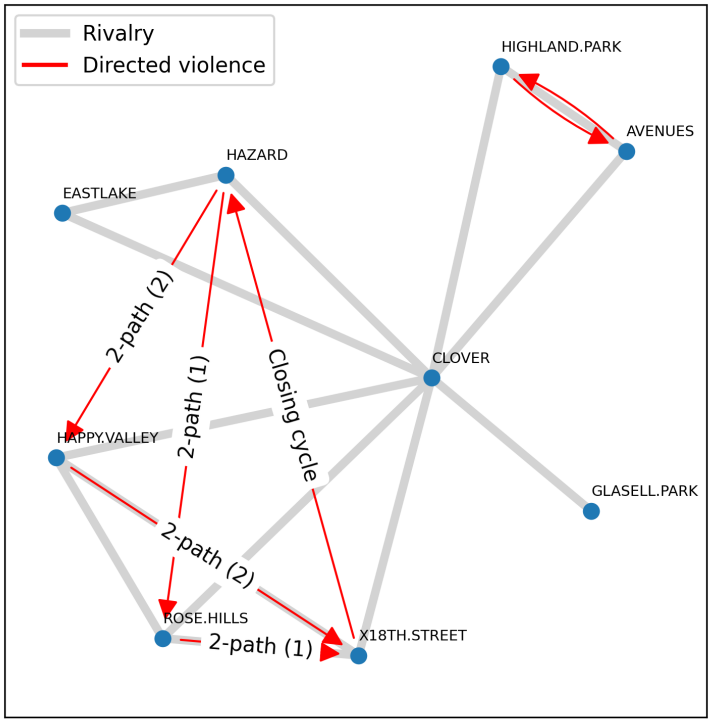


Figure 2. Map of Ramona Gardens Housing Community.

Figure 3. Ego network of Clover's rivalries and examples of violent conflicts



Note: The violent conflicts depicted are simply for illustrative purposes

Figure 4. Relative ranks of observed events

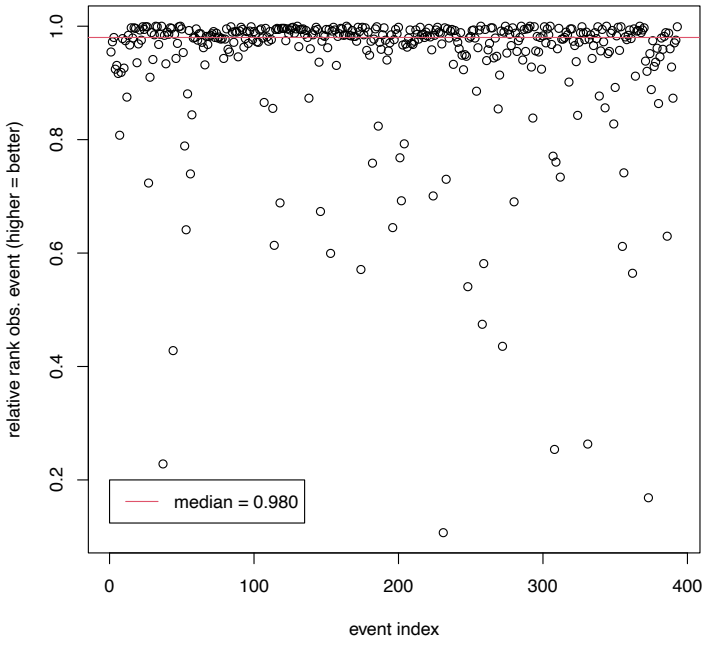


Figure 4. Predictor contribution to observed event ranks

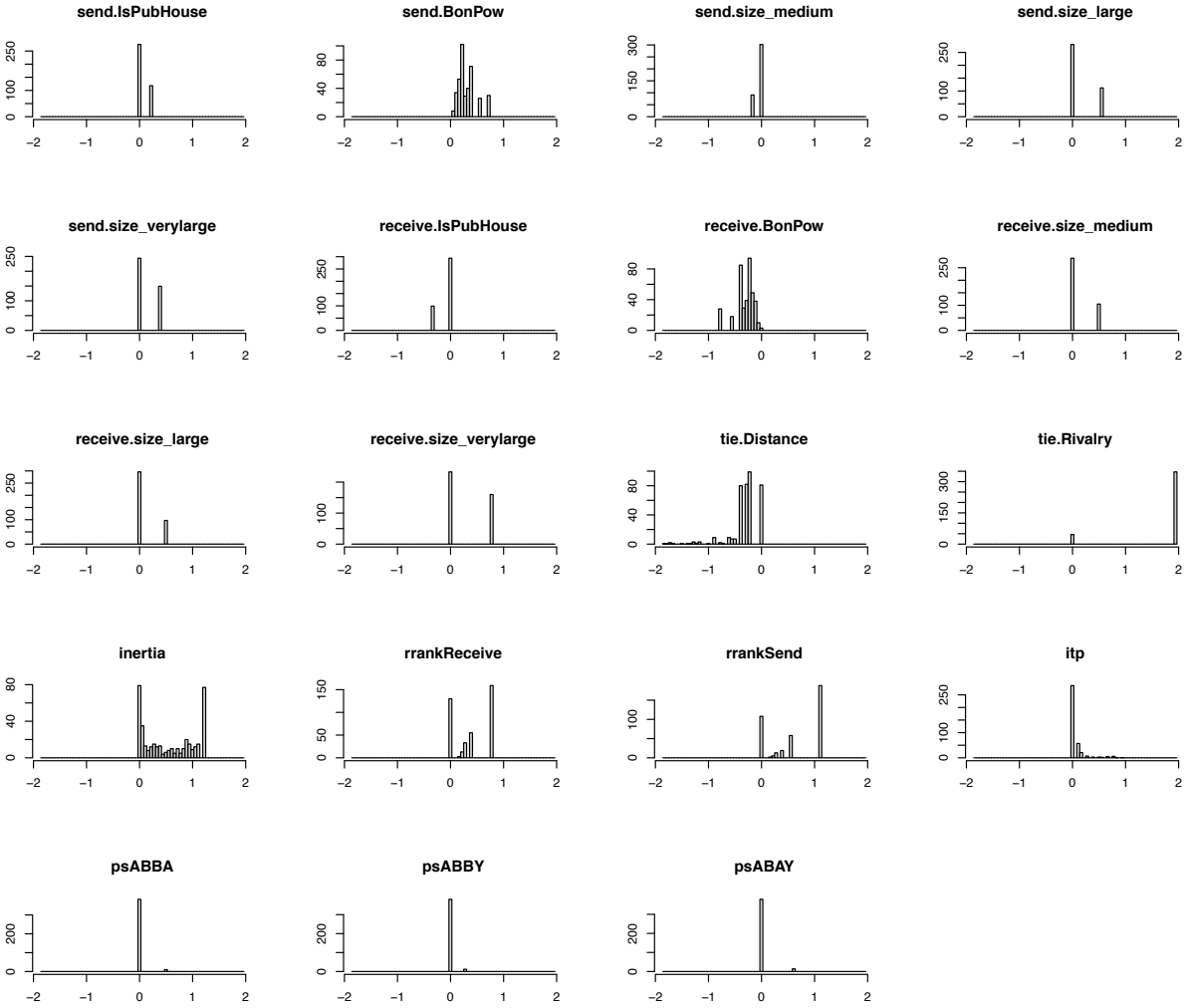


Table 1. Model parameters, examples, and interpretation

Name	Past (t_n)	Future (t_{n+k})	Interpretation
Cyclical violence (ITPSnd)	B→C→A B→D→A B→E→A	A→B (k > n)	The effect of the number of two-paths from B to A on the future rate of A's attacks on B (the enemy of my enemy is my enemy)
Target history (FrRecSnd)	A → B A → B A → C A → D	A → B (k > n)	The effect of the fraction of A's attacks that were directed towards B on A's future rate of attacks on B
Target recency (RSndSnd)	Older: A → D A → C Newer: A → B	A → B (k > n)	The effect of B's rank among A's most recent victims on the rate of future attacks on B.
Delayed retaliation (RRecSnd)	Older: D → A C → A Newer: B → A	A → B (k > n)	The effect of B's rank among A's most recent attackers on the rate of future attacks on B.
Immediate retaliation (PSAB-BA)	A → B	B → A (k = 1)	The tendency for A's attack on B to be followed immediately by B's attack on A
Imperfect retaliation (PSAB-BY)	A → B	B → Y (k = 1)	The tendency for A's attack on B to be followed immediately by B's attack on a gang different from A
Violent spree (PSAB-AY)	A → B	A → Y (k = 1)	The tendency for A's attack on B to be followed by A's attack on a gang different from B

Table 2. Parameter estimates of REM model of gang violence

	MLE	S.E.	Z-value	p-value	
Gang controls					
Rivalry	1.968497	0.201011	9.7930	< 2.2e-16	***
Distance between territory	-0.262583	0.055192	-4.7576	0.000002	***
Public housing (attack)	0.245730	0.124399	1.9753	0.048231	*
Public housing (victim)	-0.311550	0.134874	-2.3099	0.020891	*
Gang size					
Attack (ref: small)					
Medium	-0.173711	0.21246	-0.8176	0.413576	
Large	0.539612	0.20715	2.6049	0.009190	**
Very Large	0.378156	0.22865	1.6538	0.098161	.
Victim (ref: small)					
Medium	0.498571	0.22403	2.2255	0.026049	*
Large	0.511302	0.2197	2.3273	0.019949	*
Very Large	0.769944	0.2436	3.1607	0.001574	**
Bonacich Power in rivalry network					
Bonacich Power (attack)	0.283483	0.11859	2.3905	0.016827	*
Bonacich Power (victim)	-0.295206	0.11531	-2.5601	0.010463	*
Cyclical violence					
Incoming two-path (ITPSnd)	0.094810	0.03486	2.7194	0.006539	**
Inertia and recency on future attacks					
Target history (Inertia-FrRecSnd)	1.204079	0.25893	4.6502	3.32E-06	***
Target recency (RSndSnd)	1.108720	0.21559	5.1428	2.71E-07	***
Retaliation					
Delayed retaliation (RRecSnd)	0.778263	0.15818	4.9203	8.64E-07	***
Immediate retaliation (psABBA)	0.512771	0.3263	1.5715	0.116069	
Imperfect retaliation (psABBY)	0.265184	0.29692	0.8931	0.371796	
Violent spree					
Consecutive attacks on different targets (psABAY)	0.603903	0.27802	2.1722	0.029844	*
Constant	-12.995142	0.36431	-35.67	< 2.2e-16	***
Null deviance (df)		9525.485 (393)			
Residual deviance (df)		7890.836 (373)			
AICC		7933.094			

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