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Social Network Analysis in the Study of Terrorism and Insurgency: From Organization to Politics[1]

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Research using social network analysis to study terrorism and insurgency has increased dramatically following the 9/11 attacks against the United States. This research emphasizes the importance of relational analysis and provides a variety of concepts, theories, and analytical tools to better understand questions related to militant group behavior and outcomes of terrorism and insurgent violence. This paper defines key network concepts, identifies important network metrics, and reviews theoretical and empirical research on network analysis and militant groups. We find that the main focus of existing research is on organizational analysis and its implications for militant group operational processes and performance. Few studies investigate how differences in network structure lead to divergent outcomes with respect to political processes such as militant group infighting, their strategic use of violence, or how politically salient variables affect the evolution of militant cooperative networks. Consequently, we propose a research agenda aimed at using network analysis to investigate the political interactions of militant groups within a single conflict and provide illustrations on how to pursue this agenda. We believe that such research will be of particular value in advancing the understanding of fragmented civil wars and insurgencies consisting of multiple, independent militant groups.

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Scholars have increasingly applied concepts and methods from social network analysis (SNA) to problems in political science and international relations (Hafner-Burton, Kahler, and Montgomery 2009; Maoz 2011; Ward, Stovel, and Sacks 2011). A component of this methodological movement involves the application of SNA to terrorist and insurgent networks. This scholarly activity, along with the continued salience of terrorism and insurgency to contemporary conflicts, warrants a comprehensive review of how SNA can answer questions posed in research on these conflicts. In this essay, we survey how network analytic ideas and tools have been employed in the study of violent "militant groups" – a term we will use to refer to both terrorists and insurgents.[2] In our review we find the existing body of research has been oriented predominantly toward understanding the internal structure of individual militant organizations. We propose that greater attention be devoted to the network of interactions between multiple militant groups within a single conflict.

Given its organizational emphasis, research on militant networks has been primarily concerned with questions involving group operations. The theoretical literature has engaged with how network structure affects operational effectiveness: Are decentralized networks more capable and adaptive than centralized ones? How does network structure reflect the tradeoff between the need for coordination between militants and the risk that such communication may be detected by state security services? Do militant networks have a "scale-free" structure in which highly connected hubs both improve information flow and enhance robustness to random targeting by counterterrorism operations? Empirical studies that use SNA data on militant groups have, for the most part, engaged with a different set of questions. For example, these studies predominantly identify leaders, key individuals, and roles; explain clustering patterns based on similar roles, backgrounds, or ideologies; and examine how the characteristics of individual nodes relate to outcomes such as lethality, recruitment, or the diffusion of technology.

The covert nature of militant groups makes them a difficult subject to study in general, a problem that becomes particularly acute when the objective is to map out the very internal structure which militants go to great lengths to conceal. This is perhaps the principal reason for the disjuncture between the theoretical and empirical militant network literatures. While their operational aspects are necessarily covert, militant groups have another side which, equally necessarily, is public – their political face. Militant groups are engaged in a political competition not just with the state but often also against their fellow militants, a competition that forces them to declare themselves as a group and reveal, to a considerable extent, their aims, allies, enemies, and targets of violence. This visibility at the group level facilitates network analysis because identifying the "nodes" in a network precedes mapping their ties. Assessing the number of individuals within a terrorist or insurgent group is notoriously difficult whereas estimating the number of groups within a broader militant movement is a less severe problem.

A focus on groups rather than individual militants will be more amenable to empirical analysis for both historical and contemporary cases. In this essay we note several recent

[2] We use the term "militant group" throughout the paper except in the review section where we often use the terminology the author(s) of the piece employ. Terrorism is a tactic. Insurgency refers to the scale or type of conflict. Insurgents are usually capable of conducting sustained guerilla warfare campaigns against regular or irregular armed rivals. Neither concept is mutually exclusive. An insurgent group might use terrorist violence and a designated terrorist group may or may not be involved in an insurgency.

empirical studies that do so and argue that this research should go beyond the current emphasis on operational questions to consider political outcomes such as alliances, inter-militant clashes, more extreme violence, and negotiations. The thrust of this proposed line of research – studying interactions between groups with an eye toward political behavior – dovetails nicely with the growing literature on fragmented insurgencies and civil wars in which multiple militant groups contend with the state and often each other.

We illustrate how important questions within the militant fragmentation literature can be approached using an SNA framework, opening up new avenues of empirical investigation. For example, a greater degree of institutionalized coordination is claimed to be associated with a lower likelihood of militant infighting (Bakke, Cunningham, and Seymour 2012). Within SNA, a commonly observed network structure consists of a "core" of well-connected nodes surrounded by a "periphery" of more isolated ones (Borgatti and Everett 1999). A core-periphery structure can indicate that powerful groups are cooperating with each other rather than primarily seeking ties with weaker groups. One might then expect that fragmented militant movements exhibiting core-periphery structure will be less susceptible to infighting than movements in which powerful groups anchor separate constellations of weaker allies. Core-periphery militant movements might also be more resistant to "outbidding" dynamics in which competition for popular support causes groups to engage in ever more extreme forms of violence (Bloom 2004). Additional applications include the role of anarchy, ideology, and credible commitments in the formation of militant alliance networks and the use of tactical cooperation networks to gain insight into the composition of militant groups.

This paper begins with an overview of network concepts and tools in the militant context. We then review the theoretical and empirical literatures and provide an appraisal of their strengths and weaknesses, suggesting methodological improvements such as more precise characterization of ties and greater effort to investigate networks over time. Next, we present our argument for opening up a more politically-oriented research agenda and offer some candidate approaches to specific research questions which comport with that agenda. A brief conclusion follows.

Network Theory and Methods

Social network analysis examines patterns of relations, or social structure, among actors within a defined analytic boundary. Simply put, a network is a system of interconnected actors and, hence, network analysis is at heart structural analysis. This section summarizes basic aspects of SNA in the militant context: the nodes and ties which constitute a network; fundamental network metrics, methods, and concepts; and the challenges of missing data.

Nodes

Nodes in network models can represent individuals, groups, or other collections of actors such as states. While studies in international relations have commonly used states as the actors in network analysis, studies of militant violence usually focus on individual actors or groups. Krebs (2002) maps out the individual hijackers and the broader neighborhood of actors from the 9/11

attacks on the Twin Towers and the Pentagon. Koschade (2006) and Magouirk, Atran, and Sageman (2008) map individuals and subgroups from the Jemaah Islamiyah. Rodríguez (2005), Jordan, Mañas, and Horsburgh (2008), and Zech (2010) map out individual actors from the 2004 Madrid train bombings. Pedahzur and Perliger (2006) graph individuals from four different Palestinian suicide bombing networks. Helfstein and Wright (2011a) use individual level data to construct terror attack networks before drawing comparisons across cases.

Most individual-level node studies set the analytical boundary within a single group and so can be considered as intra-organizational analysis. These militant organizations have defined structure and processes for collective decision-making, their members occupy functionally different roles, some members exhibit greater influence, and members have collective goals they pursue as a unit (Crenshaw 1985). However, boundary specification, or deciding which actors to include in the network, is itself an analytical question – one for which there is no set practice and should be guided both by the research objectives and empirical limitations. Setting the boundary to include individuals beyond a single organization may be justified by the analytical questions of concern. For example, a terrorist incident such as the 2004 Madrid train bombings would not have been possible without the Spanish nationals who supplied the explosives but were unaware of any plans to carry out a domestic attack on Spanish soil (Zech 2010).

The use of group-level nodes in militant network analysis is underdeveloped as compared with scholarship on inter-organizational networks from the organizational studies and social movement theory literatures (Diani and McAdam 2003; Brass, Galaskiewicz, Greve, and Tsai 2004). A network of independent militant groups lacks the defined structure and processes that characterize a single militant organization. Inter-organizational networks can be viewed through the lens of a systems approach which emphasizes how patterns of relations enable or constrain action. Several papers which examine groups as network nodes set a transnational analytical boundary combining multiple conflicts (Asal and Rethemeyer 2008; Asal, Ackerman, and Rethemeyer 2012; Horowitz and Potter 2014). Gabbay (2008) sets the boundary within a movement engaged in the same conflict: Sunni insurgent groups in Iraq. The greater focus on militant factional politics, which we argue for later in the paper, centers on using groups as nodes.

Ties

Ties most often capture exchange and dependency relationships. Network research on militant groups can examine specific social processes or more general ties between actors in a system. Ties can represent personal relationships of family, friendship, or acquaintance (Pedahzur and Perliger 2006; Magouirk and Atran 2008). Some studies focus on communication between actors in a network and ties represent exchange of information through telecommunications, the Internet, letters, or face-to-face and indirect contact (Krebs 2002; Koschade 2006). Other studies lump ties into an all-encompassing category that can include kinship, friendship, personal contact, interaction, shared experiences, or other forms of relations (Rodríguez 2005; Magouirk et al. 2008; Zech 2010). Ties can also represent alliances or cooperation between militant organizations (Gabbay 2008; Asal et al. 2012; Horowitz and Potter 2014).

The mathematical discipline that studies the topology of networks, graph theory, defines networks as sets of node pairs and ties between them. In SNA, however, an “adjacency matrix” or “sociomatrix” is usually constructed in which the actors are arrayed along both the rows and

the columns and numerical tie values are the matrix entries (Wasserman and Faust 1994). In directed networks, separate ties are used to capture incoming or outgoing social processes whereas undirected networks represent symmetric mutual influence. Ties between actors can be binary, i.e, present or not, or valued to represent gradations in tie strength. The strength of a tie or frequency of interaction between actors might affect future social dynamics (Granovetter 1973). Differentiating between strong kinship ties and general ties may help explain bridges within and across organizations (Magouirk et al. 2008). Ties represent a wide range of social processes that can serve as a fertile testing ground for competing theories on social structures and behavior.

Network Metrics, Methods, and Concepts

After identifying the nodes and ties, social network analysis contains a variety of quantitative tools and qualitative concepts to capture the importance and roles of individual nodes, the processes occurring within the network, and the structure of the network as a whole. Table 1 lists selected metrics, processes, and methods useful in studying militant groups.

TABLE 1. Selected SNA Metrics, Processes, and Methods
(Insert Table 1 here)

Studies most commonly reference concepts that can use centrality, clustering, or density metrics. The degree of a node refers to the number of ties it has to other nodes in the system and the degree centrality metric can be used to capture the relative power, influence, or prominence of that actor. Betweenness centrality, however, captures a different type of influence, that which stems from an actor's position as a bridge between distinct subsets of nodes or communities in the network. A network density metric is a ratio of the total number of observed ties given the total number of potential ties in the system. Network density provides indication as to the connectivity of a network, the ease with which actors might communicate or coordinate with other actors in the system, or how resilient a network might be to disruption through node elimination or severing of ties. Homophily predicts tie formation based on shared nodal attributes such as religion, region of origin, sex, or age.[3]

As is common SNA practice, the tools and concepts listed in Table 1 are applied to networks of individuals and networks of groups alike. As Hafner-Burton et al. (2009) point out, however, this practice often results in insufficient attention being paid to grounding the application in processes specific to the level of analysis. For militant networks, a particular metric or concept may have different significance or interpretation at the individual and group levels. Such differences can arise from the greater degree to which intra-organizational network structure can be deliberately engineered as compared with inter-organizational networks. The structure of ties within a militant organization may reflect a fusion of the social processes between individuals at a local level and the global decision by its leaders to structure the organization in a particular way for operational purposes; militant groups often restructure themselves in response to changes in the level of repression (Shapiro 2013:16-17). There is no

[3] For further details on the metrics and methods in Table 1, the reader can consult a number of textbooks on social network analysis including Wasserman and Faust (1994), Carrington, Scott, and Wasserman (2005), Jackson (2008), and Newman (2010).

such global authority in a collection of independent groups, however, so inter-group ties predominantly arise from the system of social and political processes operative between groups.[4]

We now provide several illustrations of how the same metric can have different implications at the individual and group levels of analysis. At the individual level, a high degree centrality in a network of communication ties could signify that a node is a formally-designated operational leader whereas at the group level it could signify that the node has access to material or media resources (Diani 2003). An individual with high betweenness may serve as a leader or courier between different operational or functional cells; a group with high betweenness may have a national presence which bridges geographically distant and localized groups or a centrist ideology bridging divergent wings of an insurgent movement (Diani 2003; Gabbay and Thirkill-Mackelprang 2010). Within a network of militant groups, the density of ties may be taken as an indicator of the movement's cohesiveness. This need not be the case for the network of individuals within an organization where the density of ties may reflect a choice by the leadership – high density favoring information flow and redundancy, low density favoring covertness – with no implications for the willingness and likelihood of those individuals to cooperate absent central authority or cohere in the face of adversity.

In general, using SNA tools to identify patterns in social relations and to then draw conclusions about how those structural properties relate to outcomes requires assumptions about actors and their behavior. The nodes that represent network actors are not black boxes compelled to behave in some way based solely on their structural position. What research on militant groups may need most is an approach that recognizes and accounts for agency given structural facilitation or constraint.[5] For example, Carley (2006) and Carley, Lee, and Krackhardt (2002) suggest how policymakers might use network tools to learn how to better destabilize covert networks. While these authors demonstrate the importance of identifying influential actors, subgroups, and the structural factors that make a network more adaptive, they readily admit the problems that may emerge resulting from unforeseen effects and the "culture free" nature of this approach.

Data Challenges for Covert Networks

Existing research frequently highlights the difficulties of collecting and analyzing relational data for covert networks. The two primary sources of information have incentives to distort the truth, confounding efforts to construct an accurate account of militant networks: law enforcement, government officials, intelligence officers, and the justice system may exaggerate the extent of an individual's participation while militant actors themselves may deny or downplay their own involvement. Many militant groups take precautions to minimize their visibility to security forces and the outside world. Attributes and associations are often "missing by design," forcing scholars to recognize the problematic assumption of treating missing links as random. Working with non-random, incomplete network data leads to significant underestimation and confounds other network metrics such as centrality (Gill and Freeman 2013).

Some scholars offer strategies to overcome data limitations when studying clandestine networks. For example, Clauset, Moore, and Newman (2008) provide a technique for inferring

[4] External state sponsors often seek to force cooperation among militant groups but the mixed results of such attempts indicates that state sponsors cannot be construed as global authorities of militant movements.

[5] See Stevenson and Greenberg (2000) for a brief review on how strategies of action may relate to social structure.

hierarchical structure and then use existing observations to predict missing data for partially known networks. Gerdes (2014) proposes new methods for data transformation when working with "dark network" data. Koskinen, Robins, Wang, and Pattison (2013) describe additional methods for dealing with unobserved relational ties and partially observed attribute data so as to achieve better estimates with Exponential Random Graph Models (ERGMs).

Theoretical and Qualitative Work

In this section, we review theoretically oriented research on militants that directly engages with network theory, concepts, or formalism, advancing arguments with qualitative analysis or mathematical models. Due to space limitations, we have selected publications that are representative of major themes and debates within the literature. Table 2 summarizes these studies with respect to their contexts, concepts, analytical claims, and network characterization. The column that lists the cases in each study also notes whether the piece focuses on terrorism, insurgency, or some combination of the two. We proceed to describe the most salient areas of concern and debate for this literature: the capabilities of decentralized vs. centralized forms of militant organizations; the relationships and trade-offs between network structure and operational security, efficiency, and resilience; and application of the scale-free network concept to these questions.

TABLE 2. Selected Theoretical and Qualitative Work
(Insert Table 2 here)

Decentralized vs. Centralized Networks

The frequent yet disparate use of the term "terror network" in news reports, books, and academic journal articles illustrates the need for conceptual clarity. In recent years, scholars and policymakers have shifted their attention from hierarchical militant organizations to looser organizational forms and labeled anything without strict top-down command structure as a "network." Given that the SNA definition of network is unconcerned with the presence or absence of hierarchy, this usage amounts to shorthand for a network in which authority is decentralized. Debates have arisen as to the relative merits of centralized and decentralized networks, their applicability to specific cases, and their impact on militant behavior.

Arquilla and Ronfelt (2001) suggest that "networked" forms of organization are on the rise as many organizations and movements take advantage of new information and communication technologies. These forms may include chain, star/hub, or all-channel topologies or some combination of these forms with elements of hierarchical organization. They argue that organizations find advantage in the increased adaptability of decentralized network structure. Decentralized decision-making processes allow groups to respond more quickly to changing conditions and give them greater flexibility in catering strategies to particular contexts. Eilstrup-Sangiovanni and Jones (2008) review many of the purported benefits of decentralized structure to militant organizations but note that, despite enjoying advantages in terms of flexibility and adaptability, these organizations may not process and share information as well as their advocates suggest. They also point out problems with the speed and coherence of decentralized

decision-making and observe that, without central direction, organizations face coordination difficulties and may be prone to excessive risk-taking. The importance of trust in illicit networks may hinder scalability advantages found in their licit counterparts. Matthew and Shambaugh (2005) build on insights found in research on collective action and conclude that terrorists must evolve into more cohesive and hierarchical organizations to effectively achieve their goals, but they also argue that decentralized networks are more difficult to defeat. In-depth studies of the strengths and vulnerabilities associated with centralized and decentralized militant groups, informed by an organizational studies perspective, are found in books by Sinno (2008) and Shapiro (2013).

The focal case for this debate has been Al-Qaeda and transnational terrorism motivated by a global jihadist strain of Islamist ideology. Identifying Al-Qaeda as a hierarchical organization, loose network, or broader social movement affects assumptions and expectations about behavior that guide subsequent analysis (Jackson 2006). Two prominent terrorism experts, Marc Sageman and Bruce Hoffman, engaged in heated dispute about the nature of the threat posed by jihadist terrorism grounded in their respective characterizations of it as primarily a loose-knit ideological movement or as a more centrally-led Al-Qaeda organization (see Hoffman 2008; Sageman and Hoffman 2008). Neumann, Evans, and Pantucci (2011) recognize the amorphous nature of the Al-Qaeda movement and, using case studies, suggest that a set of middle managers play a critical role integrating grass-roots movements with top leadership.

With respect to the broader global jihadist movement, early work by Sageman (2004) provides a description of the ideas, attributes, and relations of actors involved in the global jihad. Sageman (2008) also suggests that these Islamist terror networks have evolved into more fluid and independent entities, creating a "leaderless jihad." Kirby's (2007) article on the 2005 London bombings describes a decentralized, close-knit network of "self-starters" inspired by this broader movement with no direct ties to Al-Qaeda leadership. Instead, Mohammad Sidique Khan exerted influence over his three young collaborators in perpetrating suicide bombings that killed 52 civilians and injured over 700 more. Vidino (2007) describes another group within the movement and suggests that the Hofstad group's amorphous structure and lack of ties to international Islamist groups will influence recruitment practices and target selection in future attacks in the Netherlands and elsewhere in Europe.

Carrying the debate to the insurgency context, Gutiérrez Sanín and Giustozzi (2010) claim that the degree of decentralization can explain differences in behaviors of the Afghan Taliban and the Revolutionary Armed Forces of Colombia (FARC) in their comparative study. The Taliban is characterized as a decentralized "network," the FARC as a hierarchical "army." The authors claim that these contrasting forms impose different demands for organizational survival and that there are trade-offs between them, though neither is objectively superior to the other: army-like insurgent organizations must emphasize internal cohesion while networked insurgents must actively broaden their social base, maximizing their integration with civilian populations.

Operational Security, Efficiency and Resilience

The United States Army/Marine Corps counterinsurgency field manual states that, "while high network density groups are the most dangerous, they are also the easiest to defeat and disrupt" (2007:320). This is an assertion about the trade-off between a militant group's vulnerability to

detection and its ability to effectively carry out attacks, one supported by early research on other types of illicit networks that prioritized secrecy over efficiency (Baker and Faulkner 1993). Many of the studies in our review address this trade-off between operational security and efficiency.

Eilstrup-Sangiovanni and Jones (2008) suggest that decentralized networks that compartmentalize nodes for security purposes make information transmission and complex, strategic decision-making more difficult. Enders and Su (2007) develop a formal model to address the security vs. efficiency trade-off faced by groups that use terrorist violence. The authors use the model to show that minimizing network density provides greater security for a terrorist network by decreasing the efficacy of network disruption through infiltration. They suggest that there is a critical density below which it becomes more efficient for terrorists to work in disconnected subgroups. Furthermore, counterterrorism efforts may lead terrorists to switch to less complex attacks requiring lower density which ultimately have higher probabilities of success.

The relationship of the efficiency vs. security trade-off to the resilience of a terrorist network was studied by Lindelauf, Borm, and Hamers (2011). As is commonly done, they treat resilience as a structural property of a network in terms of its ability to maintain information flow as nodes are removed. The authors claim that terrorist networks are able to operate near the optimal balance of efficiency and security even in the face of very high node attrition. Parkinson (2013) presents an interesting aspect of operational security and resilience – the use of women by Palestinian militants in Lebanon to circumvent and recover from repression. Informal social ties helped women serve as bridges between the subunits of a group and between different groups. She describes the role played by these informal social networks in helping the groups recover from severe losses in the wake of Israel's invasion of Lebanon in 1982, illuminating resilience as a process and not just as a structural property. Staniland (2014) argues that insurgent leaders do not have a free hand in the structuring of their groups, rather they are constrained by pre-war social ties. He studies how the resilience of a rebel group depends on two sets of ties: the horizontal ties connecting the group's leadership and the vertical ties between leaders and local communities. "Integrated" groups with both strong horizontal and vertical ties are most robust to counterinsurgent strategies of leadership decapitation and disembedding local communities from the group.

Scale-Free Networks

"Scale-free" networks provide one example of a system that may face an operational security and efficiency trade-off. Scale-free networks contain a small number of prominent nodes (hubs) that possess a greatly disproportionate number of ties to other nodes in the system, while the vast majority of nodes have relatively few ties. More precisely, the probability distribution for node degree falls off as a power law so that the degree distribution has a fat tail. Barabási and Albert (1999) proposed a model in which scale-free networks arise from a simple preferential attachment effect in which the ties formed by a new node with existing nodes are made with a probability proportional to the degrees of the existing nodes. So, in effect, "the rich get richer." Power-law degree distributions are empirically observed in a wide range of biological, social, informational, and technological networks such as the internet (Newman 2010: chapter 8). It should be borne in mind, however, that an important characteristic of observed scale-free social

networks – for example, movie actor co-appearances, calls of a telephone company's customers, sexual partners – is that they represent ties in a one-off nature and not as repeated bidirectional exchanges intrinsic to richer forms of social interaction, such as traditional friendships which do not follow power-law degree distributions (Amaral, Scala, Barthelemy, and Stanley 2000). A key property of scale-free networks is that they are robust to attacks against random nodes, since the vast majority of nodes have only a few connections and their removal does not appreciably affect the global connectivity of the network. Conversely, however, they are very vulnerable to the targeted removal of key hubs that transmit information or resources through a network (Albert, Jeong, and Barabasi 2000).

The scale-free network concept has been applied to militant groups primarily with respect to the importance of hubs and robustness to counterterrorism attacks and infiltration efforts. Matthew and Shambaugh (2005) refer to Al-Qaeda as a hub in a scale-free terrorist network but highlight the fragility of its position noting that hubs primarily serve instrumental purposes and do not engender loyalty. Motivated by the horizontal, not hierarchical, processes by which scale-free networks evolve, Pedahzur and Perliger (2006) draw a distinction between individuals who become informal hubs as opposed to formally-designated leaders in Palestinian suicide bombing networks. Stohl and Stohl (2007) describe ethnicity-based, "inward looking" terrorist organizations operating at the local level as reflecting a scale-free, ''small world'' network with short degrees of separation, strong ties, and powerful hubs. In contrast, they suggest that ideologically-oriented movements do not exhibit these tendencies and remain more vulnerable to infiltration and random attacks. They cite the historical record to support their claim, stating that the scale-free, ethnic-based organizations have shown greater resilience in the face of counterterrorism or counterinsurgency efforts than ideologically-oriented ones. Based on their case studies of three militant groups, Bakker, Raab and Milward (2012) claim support for the scale-free network structural property. Networks which are more centralized (the Tamil separatist group LTTE), in the sense of having a few well-connected nodes, are less robust to attacks against central nodes than groups they characterize as having a more decentralized structure (the FARC in Colombia).

Empirical Work

We now turn our attention to research that quantitatively applies social network analysis techniques to empirical data on militant groups either for the purpose of description and characterization or to test propositions about social structure. Table 3 summarizes selected empirical pieces on networks and militant violence. These represent a wide breadth of SNA tools such as centrality, network density, and ERGMs. The research also illustrates diverse sources for data and evaluates individual and group level relational data as dependent and independent variables. A salient feature of the empirical literature as seen in Table 3 is the much greater attention given to cases of terrorism as compared with insurgency. In this section, we highlight empirical research findings involving centrality, attribute-based clustering, network density, and the use of groups as nodes.

TABLE 3. Selected Empirical Work
(Insert Table 3 here)

Centrality

Research on militant networks, specifically terrorist networks, often emphasizes the importance of prominent actors on outcomes. Central nodes may have more influence on other actors in the network. Some studies provide measures for an actor's status using centrality indices. Pedahzur and Perliger (2006) stress the importance of central figures in their study of Palestinian suicide networks. The authors include degree, closeness, and betweenness centrality scores for hubs, general members, and suicide bombers for each of their four networks. They conclude that networks with a greater number of hubs will carry out more attacks and that peripheral actors usually carry out suicide attacks to limit network vulnerability in case of capture. Jordan et al. (2008) and Zech (2010) use centrality metrics to identify central actors in the Madrid train bombing network. Horne and Horgan (2012) use three distinct centrality measures to identify network elites in their study of radical Muslims in the United Kingdom. Koschade (2006) identifies two key hubs in the Bali bombing network using centrality measures.

Krebs (2002) also calculates centrality metrics in his work on the 9/11 network. He finds the scores to generally reflect "common knowledge" about individuals such as Mohamed Atta concerning leadership and influence, but urges caution in drawing conclusions based on these measures. Studies on terrorist networks are especially susceptible to missing nodes and ties and centrality measures are sensitive to minor changes in nodes and links (Krebs 2002:47). Krebs also finds the network to have an unusually long mean path length for such a small network. Krebs suggests that this metric reflects a concern with secrecy, but a network must create shortcuts and indirect connections to aid in information flow necessary for the minimum efficiency levels to carry out a complex operation. Borgatti (2006) uses the same network to illustrate the potential inadequacy of centrality measures to identify "key players" in subsequent counterterrorism operations that aim to influence or disrupt militant networks and suggests alternative measures for finding optimal sets of key players.

Clustering by Attributes

Another important concept to analyze militant networks is clustering by shared attributes. Militant actors may tend to form ties on the basis of similar roles, backgrounds, and preferences among other factors. Scholars can use network graphs to display relational data and observe whether or not actors cluster based on theorized common attributes. Koschade (2006), Zech (2010), and Gill, Lee, Rethemeyer, Horgan, and Asal (2014) demonstrate clustering based on role adoption in their network graphs. Jordan et al. (2008) suggest some degree of homophily, or the tendency for nodes to associate with like-nodes, based on country of origin in their graph of the Madrid bombing network and Spanish Al-Qaeda. Gabbay and Thirkill-Mackelprang (2011) find Sunni insurgent groups to cluster based on nationalist and jihadist ideologies. Harris-Hogan (2012) identifies cliques based on shared experiences within the Melbourne cell of the Australian neo-jihadist network. In addition to visualization techniques, scholars can use K-core analyses, which search for the largest subset where every node is connected to at least K members of the subset, to locate subgroups in networks (see Pedahzur and Perliger 2006). ERGMs can also be used to evaluate clustering based on shared attributes (see Zech 2010; Gill et al. 2014).

Density

Density scores for a complete graph may also provide useful information when comparing two or more networks. Density is the proportion of observed edges in a network to the total number of potential edges. Krebs (2002) provides a density score of 19% for the 9/11 network of trusted prior networks and meeting ties. Koschade (2006) provides descriptive structural characteristics that include a density score of 43% for the Jemaah Islamiyah 2002 Bali bombing cell. These metrics may provide some indication as to how covert particular terrorist networks are, but without a baseline for comparison any conclusions concerning the meaning of a single density score is purely speculation.

Helfstein and Wright (2011b) evaluate relational data for three categories of Al-Qaeda attack networks to test propositions about density derived from network theory. The authors differentiate these attack networks into core, affiliate, and periphery cells based on their strength of ties to Al-Qaeda's core leadership. Helfstein and Wright use these data to test the hypothesis that core and affiliate cells should demonstrate greater capacity than periphery ones, and thus will have greater network density scores. Contrary to expectation, the authors find that core cells had lower density scores than affiliate and periphery groups. They speculate that attack cells across these different levels may form differently. Small cells on the periphery may tend to be groups of pre-existing friends and acquaintances drawn to the ideology of the broader movement. These cells may be less experienced than the core in the design of secure operational structures.

Militant Groups as Nodes

While most network analysis research on militant groups focuses on individual actors as nodes, a few studies have used group-level nodes. Asal and Rethemeyer (2008) analyze group-level data in their study of organizational lethality. They evaluate the number of casualties attributed to terrorist organizations from 1998 through 2005 and find that an organization's size, ideology, territorial control, and connectedness affect lethality levels. The authors evaluate organizational connectedness using a count of relationships to other organizations intended to capture an SNA degree metric. In related work, Asal et al. (2012) use quantitative data at the organizational level to evaluate why certain groups decide to pursue chemical, biological, radiological, or nuclear (CBRN) weapons. They measure an organization's "embeddedness" with other well-connected actors using eigenvector centrality, a metric that accounts for the the extent to which a node is connected with high-degree nodes. They observe that transnational terrorist organizations with more alliances and greater embeddedness are more likely to pursue CBRN materials.

In their empirical analysis of an international set of militant organizations, Horowitz and Potter (2014) use an alliance count as well as an eigenvector centrality metric and find that groups with a broader network of intergroup relationships increase their lethal capacity. The eigenvector metric captures an "alliance depth" concept that indicates relationships to core groups involved in international terrorism. These relationships may provide greater knowledge and capabilities that increase their lethal capacity. The authors suggest a core-periphery structure in the broader network of alliances, with groups prefering to link to stronger groups.

A recent piece by Metternich, Dorff, Gallop, Weschle, and Ward (2013) also examines group-level data and provides an example of the empirical application of network-based formal modeling. Their pioneering and methodologically sophisticated analysis integrates game theory,

statistical network analysis, and automated coding of event data. The authors investigate networks of opposition parties and militant groups in Thailand and find that the inclusion of network structure – specifically, the lowest eigenvalue of the adjacency matrix – improves prediction of conflict intensity beyond contextual factors such as GDP, the nature of the government, and proximity to elections. They find that more negative values of the lowest eigenvalue are associated with greater levels of conflict directed against the government which leads them to the conclusion that less cohesive opposition movements are more effective in fighting against the government; a claim at odds with the expectation that cohesive movements typically will be more effective since, among other reasons, they can curb counterproductive behaviors such as infighting and outbidding. Such behaviors are not accounted for in the public goods model described by Metternich et al. (2013), which provides the basis for their use of the adjacency matrix lowest eigenvalue as a metric of network structure, one that has not yet been employed extensively in SNA.

Appraisal of Theoretical and Empirical Research

In this section we remark upon the strengths and shortcomings of SNA research on militants. Addressing the weaknesses we identify, such as the imprecise usage of network concepts, the lack of hypothesis testing, poorly-defined ties, and the neglect of temporal evolution and political processes, will strengthen and expand the application of SNA techniques to militants.

Perhaps the most striking feature of SNA-based work on militants is the lack of overlap between the theoretical and empirical research. Empirical studies have mostly not engaged the central concerns of the theoretical literature – the relative advantages of centralized vs. decentralized networks, the relationship between operational capability and network density, and the relevance of scale-free degree distributions – with a dedicated hypothesis testing program. A notable exception, however, is the work of Helfstein and Wright (2011a) which endeavors to test propositions about minimal network density and scale-free structure and found support for neither. This gap can be chiefly attributed to the covert nature of militant networks which greatly hampers empirical assessment of their internal structure although the often loose usage of network concepts in the theoretical literature is a contributing factor. Ultimately, the value of these theoretical debates is limited if a path to their empirical resolution is not provided.

Among the major components of the theoretical literature, the efficiency vs. security trade-off is most concrete, centering on well-defined SNA metrics such as network density. However, the centralization-decentralization and scale-free networks components have been less precise. While decentralization is consistently used in the sense of distributed authority, the domains of that authority – for example, target selection, personnel selection, operating procedures – are not sufficiently elaborated; each can have different implications for behavior and network structure. Nor does the literature adequately distinguish between lines of authority and lines of communication. The structure of the former need not be the same as the latter: a reclusive terrorist leader may communicate with his deputy via a chain of several couriers who, however, would not appear interposed between leader and deputy in the group's hierarchy. The ambiguity of the decentralization concept in the theoretical literature inhibits its consistent empirical application. For instance, the FARC has been contrastingly depicted as a decentralized

"network" (Bakker et al. 2012) and as a hierarchical "army" (Gutiérrez Sanín and Giustozzi 2010).

The concept of scale-free networks has been used primarily on a metaphorical level and not distinguished from other degree distributions in which high-degree hubs are present. A scale-free network assumes a "complex network" that continually expands with preferential attachment to hubs. Many militant groups may not expand or even seek to do so and are often too small to be considered as candidates for scale-free structure. The looser equation of scale-free structure to networks with hubs is also problematic even if one assumes that the theoretical properties of the former transfer to the latter. In covert networks the most important actors may not actually act as hubs linking up a significant number of actors. For example, a recruiter in a terrorist organization may attract preferential attachment without exerting influence over network behavior. In addition, claims that scale-free militant networks are resilient due to their robustness against random attacks on nodes have not adequately reckoned with the countervailing effect that high-degree nodes are more visible. Countermilitant forces do not simply delete nodes as do simulations of scale-free networks (Albert et al. 2000) – they can capture and interrogate them – and such a process would rapidly point to the very hubs that provide the network's information flow advantages.

Most of the quantitative empirical research is descriptive in nature, not aimed at directly testing propositions using network metrics. This descriptive work provides valuable observations that can inform theory development and more rigorous proposition testing. A number of studies have found that centrality metrics can be used to identify influential individuals within militant groups, although they do not always align with power or formal status. Metrics that identify important people can help scholars understand militant group decision-making processes and social influence, especially when combined with contextual knowledge about group leadership. Observing that terrorist networks have relatively long mean paths provides evidence that network data can shed light upon the efficiency vs. security trade-off. Network visualizations which show nodes clustering by common attributes such as functional roles, shared experiences, or ideology suggest the types of homophily that are important in driving network structure.

In a sign of progress, recent empirical work has placed greater emphasis on proposition testing. ERGMs have proven useful in this endeavor. Using individual-level nodes, Gill et al. (2014) investigate the factors that shaped network structure in the PIRA during the "Troubles" in Northern Ireland; Helfstein and Wright (2011a) investigate how network structure affects attack severity. Structure has also been used as an independent variable in networks of groups to investigate outcomes such as CBRN activities and lethality as discussed above (Asal et al. 2012; Horowitz and Potter 2014).

The dearth of proposition testing is one shortcoming of the empirical body of research on militant networks. Another is the use of implicit, poorly characterized relational ties in many studies. Some analyses use relational data coded to cover a wide range of social exchange. Studies by Rodríguez (2005), Magouirk, Atran, and Sageman (2008), and Zech (2010) operationalize social ties as an all-encompassing category that can include kinship, friendship, personal contact, interaction, shared experiences, or other forms of relations. While such a measurement certainly helps in providing a preliminary visualization to begin studying a network, this approach is less suited for studying specific militant group behaviors and testing hypotheses derived from existing theories. In Tables 2 and 3 we explicitly identify the various social processes that ties represent in select qualitative and quantitative research. When scholars collect relational data for network analysis, disaggregating actor ties in terms of communication

networks, exchange of material resources, or specific types of cooperation will better allow investigators to theorize about and generate predictions concerning actor behavior. Greater attention to specifying functions and tie types will also allow for clearer interpretation of centrality metrics, the significance of which depends upon assumptions about the underlying flow process, such as information transmission or attitude change, occurring over the network (Borgatti 2005).

An additional limitation of the empirical studies is that they largely examine static aggregate networks, ignoring how networks change over time. Researchers who collect relational and attribute data across multiple time periods for the same network can begin to substantiate claims concerning how network density, shifts in leadership, or subgroup task specialization lead to outcomes of militant violence or how these structural factors may influence decision-making, recruitment, or other behaviors. For example, Zech (2010) maps out the Madrid train bombing network for the ten years leading up to the attacks. He finds that important actors bridged the necessary subgroups in the network during the three years leading up to the attack. The change in network structure resulted from post-9/11 Spanish counterterrorism efforts and social ties that developed when two actors shared a prison cell in the years leading up to the attacks. Magouirk et al. (2008) demonstrate the importance of Jemaah Islamiyah leadership structure using network data across two time periods; one representing ties and leadership influence between 1993 and 1995 and the other in the year 2000. The social ties of central actors differed between periods and these connections influenced leadership decisions to use violence. Gill et al. (2014) examine the PIRA across four time periods. Dynamic network models can aid in exploring a group's life cycle, growth, and decay. Research that demonstrates a change in networks after the introduction of some type of intervention can begin to evaluate the effects of countermilitant policies on observed behaviors and the resulting outcomes.

Both the theoretical and empirical literatures on militant networks exhibit an overwhelming focus on operational and organizational characteristics. The debate about the structure of these networks centers around issues of efficiency, resilience, robustness, and information sharing – properties that share much in common with technological systems like the internet and communications networks. Nodes are usually taken to be individuals rather than groups and network analytic concepts and metrics are employed to identify leaders, roles, and functional communities. These are certainly important properties and features of militant groups, particularly given their covert and often informal nature, but they are primarily issues of organizational analysis. In this perspective, the network structure of a militant group influences the dimensions of a group's effectiveness such as lethality or survivability, analogously to how the structure of employee relationships influences the success of a business in terms of its sales or innovativeness. The existing research largely consists of applying concepts from other fields such as network science, management and organizational studies, and sociology. This focus underdeploys theories and insights from political science itself. The considerable attention devoted within the terrorist network literature to scale-free networks, an idea from physics, is an example of this reliance upon other disciplines for research guidance and priorities.

Beyond the Organization: Militant Networks as Political Networks

While not denying the relevance of the organizational emphasis predominant in the first wave of militant network studies, we contend that a second track emphasizing the application of network analytic methods to intrinsically political questions needs to be opened. Terrorist and insurgent groups are rooted in political goals, yet quintessential matters of politics – for example, alliance dynamics, factional rifts and infighting, splintering, the legitimate targets of violence, rhetoric, and conflict resolution – have received scant attention from a network perspective. A growing body of research within the field of insurgency and civil war studies considers such behaviors for conflicts with multiple groups. Examples include: alliance formation (Bapat and Bond 2012; Christia 2012); inter-militant clashes (Fjelde and Nilsson 2012); the effects of repression on cooperation (McLauchlin and Pearlman 2012); competitive "outbidding" toward more extreme violence (Bloom 2004); the effect of fragmentation on conflict duration (Findley and Rudloff 2012); and spoilers in negotiations (Kydd and Walter 2003). By providing a quantitative framework for representing and analyzing fragmented conflicts, a network approach could bring both greater insight and precision to the study of militant interactions.

A research agenda for connecting network analysis with political dynamics among militants calls for the following elements: (i) defining nodes at the group level rather than at the level of individuals; (ii) the use of precise and well-defined tie indicators of cooperative and/or competitive relationships between groups; (iii) the integration of politically-relevant node attributes – power, ideology, targeting practices, territorial presence, state sponsors, etc. – with the network tie data; and (iv) a focus on political questions within a single conflict such as alliance formation, militant infighting, ideological or policy repositioning, and conflict resolution. The first element stems from the fact that the group is the locus of greatest political visibility and salience – a public face not a covert one. The second element echoes our call above for more well-defined tie measures. The third element brings in key political variables which can be directly related to network structure as causes or outcomes and also provide competing or complementary explanations of the behaviors under investigation. The fourth element restricts our concern to groups involved in the same conflict rather than setting a more expansive boundary which includes transnational interactions between militant groups involved in different conflicts (Asal and Rethemeyer 2008b; Asal et al. 2012; Horowitz and Potter 2014). Groups involved in a single conflict have the potential for much more intense competition which can greatly alter their patterns of interaction relative to behaviors found in transnational networks.

Strides toward the above approach have been made. The paper by Metternich et al. (2013) on anti-government groups in Thailand represents one example. Another example is Gabbay's (2008) analysis of Sunni insurgent groups in Iraq using militant group rhetoric as data. Cooperative tie networks at the leadership and tactical levels are constructed using joint statements and claims of joint operations respectively. A "targeting policy" variable based on the portfolio of target classes – for example, US forces, government security forces, government civilians, Sunni and Shiite civilians – that insurgent groups claim to attack is used as a policy measure. He constructs a measure of a group's overall influence using the prominence of the group within the rhetoric of all the other groups. These measures are integrated in "factional map" diagrams which are used to address political questions involving insurgent constituencies, goals, cohesion, and negotiations. More generally, this work shows the value of rhetoric as a source of data on militant networks.

The remainder of this section illustrates how to apply network theory and methods to questions involving militant group infighting, outbidding, alliance formation, and constituencies. Consistent with the call to focus on single conflicts, we assume each network consists of militant

groups – terrorists or insurgents – participating in a violent, non-state opposition movement aimed at a regime, foreign occupation, or rival ethnic or religious group. We present approaches for using network analysis to address open questions in the literature on militant fragmentation such as how patterns of fragmentation affect the likelihood of inter-militant clashes or their use of extreme violence and the role of anarchy and ideology in shaping militant alliances.

Militant Infighting

Fragmented militant movements are prone to infighting (Fjelde and Nilsson 2012). A network approach would investigate: (i) how the susceptibility to infighting at a systemic level relates to network structure; and (ii) whether the network positions or roles of individual groups affect their likelihood of clashing with other militants. We suggest approaches to the first question using several ways of assessing network structure and our example approach to the second question considers the mismatch between a group's centrality and its size.

Bakke et al. (2012) propose characterizing militant fragmentation by three key variables: the number of groups, the level of institutionalization, and the distribution of power. The authors combine these independent variables into hypotheses concerning the probability and pattern of infighting. Given a conflict consisting of many groups, a network framework can be constructed which complements this theory of fragmentation enabling a more precise and direct way of testing its implications. Network density can be used to quantify institutionalization. Core-periphery structure and assortativity can visually and quantitatively account for how institutionalization and the distribution of power intersect. Community detection algorithms can provide a potentially more telling alternative to the number of groups.

Bakke et al. (2012) state that institutionalization improves the overall cohesion of a movement, thereby reducing the odds that groups will turn their weapons against each other. They define a movement as strongly institutionalized if it has an overarching institution, such as a popular front, central committee, or government-in-exile, which ties groups together whereas informal coalitions and alliances are considered indicators of more tenuous institutionalization. This suggests that a network of cooperative ties between groups, particularly at the leadership level such as joint statements, can be used to quantify institutionalization on a continuous scale. One approach would employ network density as a measure of institutionalization. Social network theory commonly associates the number of ties within a network with its cohesion (Friedkin 2004). Making the connection between network density and institutionalization leads to the expectation that increasing network density decreases the probability of militant infighting.

Network density, however, may be a problematic measure for cross-case comparison since there might be considerable variation in the rate at which tie indicators are generated and observed across conflicts, which need not correspond to differences in movement cohesion. A more refined approach integrates the distribution of power and institutionalization variables by using centrality measures as a proxy for group power. If one takes a group's degree centrality as a reflection of its overall power in terms of its size, material resources, and popular support, then the distribution of group degree centralities should correspond with the distribution of group power. Doing so allows us to account for how different patterns of network structure may affect the cohesion of a militant movement beyond simple tie density. We consider a multipolar situation in which there are a relatively small number of powerful groups and a much larger number of weaker ones. A movement in which the powerful groups are preferentially tied to one

another will be more cohesive than one in which powerful groups are tied to weaker ones and not each other. In the former case, the groups whose infighting would be most debilitating to the movement have good cooperative relationships; in the latter case, those same groups do not cooperate, instead they head rival alliances. Network visualizations and metrics can capture these distinct patterns.

In visualizations, the better institutionalized situation above will exhibit a core-periphery network structure in which nodes with high degree centralities form a dense core of ties surrounded by a periphery of low centrality nodes. In contrast, the more poorly institutionalized case will be characterized by a multiplicity of star-like network patterns, each with a powerful node at its center linked to weaker nodes. This correspondence leads to the expectation that networks with a core-periphery structure will be less prone to infighting than networks in which powerful actors are dispersed from each other.

Turning to a metrical representation, the tendency of a network to preferentially connect high centrality nodes with each other is quantified by the degree assortativity (Newman 2010:230). Networks in which that tendency is present have positive degree assortativity and are said to exhibit assortative degree mixing, whereas networks in which high centrality nodes preferentially connect with low centrality ones have negative degree assortativity and are said to exhibit disassortative degree mixing.[6] Assortative networks tend towards a core-periphery appearance whereas in disassortative networks high-degree nodes form the nuclei of the dispersed star-like clusters noted above. Therefore, analogously to the visualization case, assortative networks should exhibit a lower probability of infighting than disassortative ones.

Network analysis also provides a potential alternative to the number of groups as an indicator of fragmentation, namely the number of factions. Algorithms for detecting community structure use the pattern of ties between nodes to assign them to distinct clusters (Girvan and Newman 2002). These algorithms could be used to identify factions of militant groups. Scholars could then test whether the number of militant factions is more strongly associated with infighting than the number of groups. Furthermore, the number of factions could be related to the stability of a militant movement similarly to how the polarity of the international system affects its stability (bearing in mind the existence of the regime as a separate pole).

We now address the question of what network position may indicate about an individual group's propensity for fighting its fellow militants. The assumption made above that degree centrality faithfully reflects group power need not always be fulfilled. Two groups of the same size may have different degree centralities because one is more insular than the other, preferring to work alone or more wary of infiltration. Of particular concern is the case when a large group does not cooperate with others commensurately with its size so that there is a shortfall between the group's degree centrality and its non-network power as gauged by its military capabilities, resources, and territorial control. Powerful groups that abstain from participation in the cooperative mechanisms of the movement harm its overall level of institutionalization, thereby raising the potential for infighting (Bakke et al. 2012). Consequently, a group whose relative degree centrality is much lower than its relative size should be more likely to clash with other groups (assuming it is not geographically remote from them). This expectation is analogous to that of the status inconsistency theory of international conflict which Maoz (2011) formulates using network theory, finding empirical evidence that states whose centralities fall short of their hard power capabilities tend to act more belligerently.

[6] Although assortativity can be used as a synonym for homophily, we use it specifically in reference to degree mixing in this paper.

Outbidding

We consider how network structure may play a role in militant policy dynamics, specifically, the use of violence against civilians. Policy dynamics can be viewed as a network process in which a group's policy evolves as a function of the policies of its network neighbors. In particular, policy dynamics can be treated as a "social influence" process which holds that connected nodes experience convergent forces toward greater similarity. Formal models of social influence networks have been developed for behaviors such as opinion change (Friedkin and Johnsen 2011). Here we discuss the potential implications of social influence for outbidding.

Outbidding is an important route toward extremism arising from competition among multiple militant groups (Bloom 2004; Nemeth 2014). Outbidding can lead to more extreme types of violence, such as the indiscriminate mass targeting of civilians, because rival groups competing for popular support strive to outdo each other by conducting increasingly spectacular attacks. However, the same institutional mechanisms that dampen the potential for conflict between militants can also moderate pressures toward outbidding. Powerful groups interconnected by a web of strong cooperative ties, as in a core-periphery network, will have mechanisms to help manage the competitive pressures that could trigger spirals of extreme violence. The powerful core can provide a brake against a movement-wide slide toward extremism when isolated, weaker groups try to increase their popular support via more extreme violence. This resistance toward outbidding in core-periphery networks arises from a social influence process. Assuming the core prefers a relatively moderate use of violence, the social influence within the core will make it more difficult for a group which shifts to an extreme policy to drag the others with it by its direct influence alone.[7] Conversely, a disassortative network structure indicates competition among powerful groups thereby increasing susceptibility to outbidding dynamics. This assumes the operation of social influence forces from other levels, in particular a group's rank-and-file or the population at large: if a given group's rank-and-file start defecting to a more extreme group, then the group will feel pressure to become more extreme itself. Such a dynamic speaks to the utility of a multilevel network conceptual framework as noted below.

Alliance Formation

Whereas the preceding examples concerned the significance of network structure to militant behavioral outcomes, the question of militant cooperation and alliance formation concerns the processes which influence that structure. In organizational studies, networks of strategic alliances between corporations have been found to exhibit a core-periphery structure indicating a preference for high status firms to ally; they also display an endogenous mechanism whereby existing ties and structural positions are reinforced over time (Gulati and Gargiulo 1999). Whether or not networks among militant groups also exhibit these tendencies is an unresolved

[7] An indirect influence may be possible, however, if the extreme violence changes the very nature of the conflict which could force a movement-wide shift. For instance, if an extremist group is successful in triggering an escalation of communal violence, fellow militants, who would prefer to focus their struggle against the regime, may have no choice but to fight rival ethnic or sectarian forces as well.

question. One fundamental difference between the corporate and militant contexts is the severe cooperation under anarchy problem characterizing the latter. Accordingly, one line of research would address how the anarchical environment shapes militant network structure. Anarchy is a core concern of international relations theories and here we focus on two issues surrounding its potential effects on militant network structure: the insignificance of ideology or social identity and credible commitment problems.

In neorealist theory concerning alliance politics among states, the distribution of power and the associated balancing and bandwagoning dynamics are afforded nearly all causal power, whereas ideology and social identity are of slight reckoning (Walt 1987). Christia (2012) adapts this neorealist paradigm to alliance formation during insurgencies and civil wars, arguing that power calculations drive alliance shifts as groups seek minimal winning coalitions; ideology and social identity are claimed to play no sustained causal role. In this view, one would not expect homophily in these soft variables to be a significant factor shaping militant cooperative networks, at odds with homophily's status as a fundamental process within social network theory. However, the neorealist account of alliance formation between states is disputed by those who argue for an important role for ideology and identity (Barnett 1996). For example, a network analysis of interstate alliances has empirically observed the presence of homophily involving democratic regime types and cultural attributes (Maoz 2011:367). Similarly, network analysis could identify whether homophily is a significant process in the formation of cooperative ties and alliances among militant groups in a conflict. Beyond testing blanket, time-independent propositions about homophily's presence or absence, a more highly resolved approach would consider the conditions and phases in a conflict which affect the balance between ideologically and power-driven alliance choices. Ideological differences may at first be obscured in an insurgency which arises suddenly in response to a foreign invasion or a violent regime crackdown on protests but may reemerge as the conflict matures.

Irrespective of ideology, the level of threat from counter-militant forces should be important to the evolution of militant network structure. Initial intuition would expect that a high level of threat would encourage cooperation among powerful groups thereby fostering a core-periphery structure among militants whereas more disassortative structures would evolve at lower threat levels. However, the credible commitment problems generated by anarchy – there is no authority to enforce militant alliance agreements – may counteract this intuition. Using game theory, Bapat and Bond (2012) claim that militant dyads are more likely to overcome commitment problems when opposed by a weakly repressive regime. When taken to the network level, this dynamic leads to the expectation that core-periphery structures would arise at lower, not higher, threat levels.

Another potential manifestation of the credible commitment problem concerns the stability of militant network structure. An argument in favor of stable network ties would contend that militant groups that overcome the commitment problem to cooperate successfully would be more likely to collaborate again. Repeat interactions among trustworthy partners is one mechanism that leads to stable networks in the corporate context (Gulati and Gargiulo 1999). In contrast, Christia (2012:32-34) argues that the commitment problem faced by militants is so intense that it nullifies cooperation histories and trustworthiness, leading to the conclusion that militant alliance networks will be plagued by instability.

The contrasting predictions above concerning anarchy's impact on network structure can be empirically tested. Care should be taken as to how alliance is operationalized. Various definitions that encompass general forms of cooperation have been used (Bapat and Bond 2012;

Christia 2012; Horowitz and Potter 2014), but it is also possible to more precisely employ formal alliance declarations among militant groups as indicators of alliance ties. For instance, groups have declared numerous mergers and fronts in the Iraqi and Syrian insurgencies (Siegel 2010; Szybala 2013). Ideology or social identity could be coded via manual or automated content analysis of militant rhetoric, for example by examining the frames they employ (Gabbay and Thirkill-Mackelprang 2011; Johnston and Alimi 2012). The level of threat faced by militants could be gauged by the size of opposition forces from the regime, paramilitaries, or foreign forces or by the intensity of violence.

Constituencies

The ability to assess group composition is important with respect to political behavior because militant field commanders and fighters often shift their affiliation between groups. Hence, militants at the local level can be regarded as constituents whom groups attempt to win over, not merely subordinates to be commanded. And, as with domestic party politics, a group's constituents constrain its freedom to maneuver in pursuing political ends and means. Divisions between constituencies within a group's rank-and-file can ultimately lead to its splintering, and so, methods for inferring group composition can aid in the investigation of the causes of fragmentation, an underdeveloped and challenging area of research (Bakke et al. 2012). Gleaning insight into a group's constituencies among its active supporters is possible even when given only group-level node data. In particular, we discuss how inferences about the social identity composition of groups can be made from community structure and betweenness in the network of tactical cooperation among groups.

Militant group field units often have considerable freedom in cooperating with the field units of other groups without explicit guidance from their leadership; such tactical cooperation occurred during the anti-Soviet insurgency in Afghanistan (Rubin 2002:229-30). In this horizontally-driven process, homophily among units with similar social identities would likely play a significant role in the initiation of contacts and subsequent collaboration between field units. In terms of network structure, homophily would cause the network of tactical cooperation to exhibit a community structure in which groups cluster according to the salient social identities – religious, ethnic, tribal, nationalist, etc. – among the militants. Groups of hybrid composition, however, could cross the divide between social identities. Given its use in measuring the extent to which a node acts as a bridge linking distinct node clusters, betweenness could therefore serve as a surrogate for the extent to which a group is of mixed social identities. Evidence for clustering by social identity comes from Iraq where the joint operations network showed clear jihadist and nationalist divisions (Gabbay 2008; Gabbay and Thirkill-Mackelprang 2010). Furthermore, the group with highest betweenness, the Islamic Army in Iraq, bridged the jihadist and nationalist factions leading, along with other indicators, to the inference that it was a hybrid jihadist-nationalist group. Politically relevant observations are that the hybrid composition of the Islamic Army in Iraq may have helped it become the largest group and, on the flip side, this mixed constituency meant that its leaders had to appeal to constituencies whose ultimate goals were in opposition, a constraint that had serious implications for its cohesion.

While the group-level tactical network can be used to make inferences about group composition, a fuller representation would use a multilevel network framework which would include: (i) organizational ties between group leaderships; (ii) membership ties affiliating local

units or individuals with group leaderships; and iii) cooperative ties between local units or individuals. Within the broad SNA field, however, multilevel networks have proven easier to conceptualize (Brass et al. 2004; Moliterno and Mahony 2011) than to implement empirically. There is a paucity of true multilevel network data sets given their higher data demands and standard SNA tools such as ERGMs have only recently been extended to the multilevel context (Wang, Robbins, Pattison, and Lazega 2013). Assembling a multilevel data set for militants is likely to be especially difficult given their covert nature at the individual level. Shy of empirical implementation, multilevel networks are still likely to have value as conceptual frameworks; for instance, in the consideration of multiple levels of social influence as in outbidding dynamics.

Conclusion

Social network analysis complements conventional approaches to terrorism and insurgency studies (Perliger and Pedahzur 2011). SNA has made significant contributions to understanding militant operations regarding questions such as the relative merits of centralized and decentralized structures, the relationship between efficiency and security, the network signatures of key individuals, and the factors that shape network structure. However, the alignment between the theoretical and empirical fronts must be improved. Theoretical studies would benefit by more tightly invoking network concepts. Empirical analysis would profit from the more precise use of relational data and a greater emphasis on temporal factors. Overall, scholars must endeavor to move beyond description toward explanation, comparing a sample of similar networks or observations of the same network over time.

Existing research gives short shrift to political processes. It is largely focused on operations and organizational theory and primarily evaluates network structure using individual-level nodes. Consequently, we have outlined a research agenda which applies network analysis to intrinsically political questions, entailing a focus on group-level nodes engaged in the same conflict. We illustrated this agenda with subjects relevant to research on militant fragmentation: infighting, outbidding, alliance formation, and group constituencies. Violent conflict and alliance dynamics are matters with which international relations scholars are well acquainted, but constituencies is a term more frequently associated with those who study domestic party politics. This highlights the hybrid nature of fragmented militant movements in which the anarchical aspects of the international system are mixed with elements of political party competition: like a state, a militant group may need to decide upon a balancing or bandwagoning response to a rival who could turn its guns against the group; like a political party, the group may also worry about that same rival winning over the group's constituents. This complexity poses a great challenge to theory development, one which we believe will be more readily met by the application of network analysis, through both hypothesis testing using network theory and metrics and the development of formal models which employ a network framework.

Finally, in characterizing the study of militant networks, the distinction between analogy and model drawn by Snidal (1985) is helpful. Analogies transfer propositions from a different system to the system of interest and, hence, their logic is external and inductive in nature whereas models have an internal and deductive formal logic. Much use of analogy has been made in militant network analysis, understandable given the opacity of its subjects. The simplest use of analogy is the generic application of SNA concepts and metrics without attention to a

particular process or context. A better approach argues for the relevance of an analogy with a more developed context such as corporations, social movements, political parties, or states. However, the hybrid nature of the militant context implies that no single analogy will serve well; models with the unique logics of terrorism and insurgency will have to be built. Progress from analogies to models will be best achieved when SNA practitioners pay close attention to the specific processes identified by conventional analytical approaches to violent militancy. This synthesis will, in turn, lead to both new theoretical insights and more solid footing for empirical results.

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TABLE 1. Selected SNA Metrics, Processes, and Methods

	Meaning	*Concepts/Behaviors*
Node Metrics		
Degree Centrality	How connected a node is in terms of its number of ties	Leadership, prominence, influence, power
Betweenness Centrality	How important a node is as a bridge for connecting other nodes	Brokerage, controlling information flow, structural holes
Closeness Centrality	How close a node is on average via the shortest paths to the other nodes	Ability to send/receive information to/from other nodes
Transitivity	Tendency of nodes who are tied to a common other to also be connected	Triad closure, clustering, cohesion, role adoption
Network Metrics		
Network Density	Ratio of number of actual ties to maximum possible number of ties in network	Connectivity, cohesion, effectiveness, coordination, information sharing, resilience
Degree Distribution	Probability of finding a node with a given degree	Scale-free networks, hubs, information flow efficiency, resilience
Degree Assortativity	Extent to which nodes with similar degrees are preferentially tied	Core-periphery structure, alliance or rivalry of powerful actors
Mean Path Length	Average number of ties traversed in shortest paths between all node pairs	Information or resource flow, small-world effects ("six degrees of separation")
Processes		
Homophily	Tendency of nodes with common attributes to develop ties	"Birds of a feather," opportunity or choice-driven ties
Preferential attachment	Greater probability of new nodes to form ties with high-degree nodes than low-degree ones	Scale-free networks, hubs, "rich get richer"
Methods		
Community Detection	Finding distinct communities using patterns of ties within and across network subsets	Factions, cells, compartmentalization
Visualization	Depicting information about network structure and individual nodes	Topology, communities, homophily, core-periphery, leaders, brokers
Exponential Random Graph Models (ERGMs)	Simulation of random tie formation conditioned on specified network properties	Endogenous structural effects, closure, reciprocity, homophily

TABLE 2. Selected Theoretical and Qualitative Work

Paper	*Cases (Conflict Type)*	*Concepts*	*Selected Analytical Claims*	*Node Type*	*Tie Type*
Arquilla and Ronfeldt (2001)	numerous illustrative cases (insurgency, terrorism, social movements)	leadership, authority, typology	the network form of organization is on the rise, networked organization provides advantages in terms of adaptability and resilience	individual actor or group	communication, broad relations
Eilstrup-Sangiovanni and Jones (2008)	Al-Qaeda, other examples (insurgency and terrorism)	scale-free, centralized vs. decentralized	decentralized networks have serious deficiencies: poor information sharing, poor strategic decision-making, excessive risk-taking, and obstacles to collective action	individual actor or group	organizational membership
Enders and Su (2007)	Al-Qaeda, other examples (insurgency and terrorism)	hubs, density	there is an information flow vs. security trade-off, higher network density increases vulnerability of the group	individual actor	communication
Gutiérrez Sanín and Giustozzi (2010)	Colombia and Afghanistan (insurgency)	leadership, homophily, resource flow, centralized vs. decentralized	insurgents can be classified on an army-network spectrum, the FARC is centralized army and the Taliban is decentralized network	individual actor	general interaction
Jackson (2006)	Al-Qaeda (terrorism)	leadership, authority	groups can be better understood by classifying tie with respect to authority relationships, command and control structure affects strategy and efficacy	individual actor	communication, info. exchange, convey authority
Kirby (2007)	London bombing (terrorism)	leadership, cohesion, clique	"self-starter" cases lack a wider network of support and experience heightened small-group dynamics	individual actor	friendship, communication, joint activities
Matthew and Shambaugh (2005)	Al-Qaeda (terrorism)	scale-free	networks face collective action problems which limit ability to form consensus on goals	individual actor or group	general interaction
Parkinson (2013)	Palestinian groups in Lebanon (insurgency)	brokerage	informal social ties allowed women to bridge cells and to help groups withstand and recover from repression	individual actor	friendship, kinship, communication
Sageman (2004)	Global Salafi Jihad (terrorism)	cohesion, homophily, small-world, hubs, cliques	global Salafi Jihad is a scale-free, small-world network	individual actor	friendship, kinship, communication
Staniland (2014)	Kashmir, Afghanistan, Sri Lanka (insurgency)	leadership, cohesion, network typologies	pre-war social ties constrain insurgent forms of organization; groups with strong horizontal and vertical ties most resilient	individual actor and local communities	general interaction
Stohl and Stohl (2007)	numerous illustrative cases (insurgency and terrorism)	information transmission, social capital, scale-free, homophily, small-world	ethnic terrorist groups like Hamas or ETA are scale-free, small-world which are harder to penetrate, but once known easier to monitor and destroy	individual actor or group	general interaction
Vidino (2007)	Hofstad group in the Netherlands (terrorism)	leadership, cohesion, info. transmission, sub-groups	network structure informs target choice, recruitment and leadership less important for homegrown terrorism	individual actor	friendship, shared ideology

TABLE 3. Selected Empirical Work

Paper	*Cases (Conflict Type)*	*Metrics/ Methods*	*Concepts*	*Selected Analytical Claims*	*Node Type*	*Tie Type*	*Data Sources*
Asal, Ackerman, and Rethemeyer (2012)	global set of terrorist organizations (terrorism)	centrality	alliance	connectivity measures positively related to use or attempted use of CBRN weapons	terrorist group	alliance	Memorial Institute for the Prevention of Terrorism (MIPT)
Asal and Rethemeyer (2008a)	global set of terrorist organizations (terrorism)	centrality	alliance	more alliances related to higher likelihood of using lethal violence	terrorist group	alliance	MIPT
Gabbay (2008b)	Iraq (insurgency)	centrality, visualization	homophily, influence, alliance	cooperation related to targeting policy proximity; leadership and tactical networks show different structure	Sunni insurgent group	number of joint operations, joint statements, and references between groups	translated statements from Jihadist websites and interviews on U.S. Open Source Center
Gill et al (2014)	the PIRA in Northern Ireland (insurgency and terrorism)	ERGMs	homophily, role adoption	homophily based on gender, age, proximity, other involvement measures like geography and role	individual actor	co-involvement friendship, blood relative, marriage ties	network and attribute data collected for the study
Helfstein and Wright (2011a)	11-M Madrid train bombings, Southeast Asia incidents (terrorism)	density, ERGMs, cross-case comparison	effectiveness scale-free, trust	greater density and cohesion as attack approaches, scale-free network structure not as prevalent as thought	individual actor	communication, personal interaction, kinship	Global Transnational Terrorism (GTT) database (also called JJATT)
Horowitz and Potter (2014)	global set of terrorist organizations (insurgency and terrorism)	eigenvector centrality	alliance, core, periphery	terrorist alliances have core-periphery structure with preferential attachment to stronger groups	terrorist group	alliance	Terrorism Knowledge Base (TKB)
Jordan, Mañas, and Horsburgh (2008)	11-M Madrid train bombings (terrorism)	centrality, degree distribution, clustering	leadership, cohesion, sub-groups, homophily	advantage in autonomy, weakness in need for contact with social environment, centrality metrics do not always indicate importance, network clusters by role	individual actor	communication, personal interaction, family	court indictment, testimony, newspapers
Koschade (2006)	Jemaah Islamiyah (terrorism)	centrality, clustering, density	leadership, role adoption, cohesion, bridges	low density more stable but less efficient, centrality captures importance but not always power	individual actor	communication interactions, frequency and duration	case study through secondary sources
Krebs (2002)	9/11 attacks (terrorism)	centrality, density, mean-path	info. and resource transmission, leadership,	efficiency for secrecy trade-off, use caution in drawing conclusions from centrality	individual actor	general contact, meeting	newspapers, Internet, Moussaoui indictment

			cohesion, effectiveness, size	metrics, covert networks distinct from normal social networks			
Magouirk and Atran (2008)	Jemaah Islamiyah (terrorism)	clustering	cohesion, homophily	"bottom-up" network development and not just "top-down" indoctrination important in extremist violence	individual actor	acquaintance, friendship, family, common madrassah or training camp	GTT database
Magouirk, Atran, and Sageman (2008)	Jemaah Islamiyah (terrorism)	clustering, degree distribution, visualization	leadership, hubs	shifting group strategy based on structure and leadership (moderates sidelined in org.)	individual actor	communication, personal interaction, kinship, reliability	media accounts, other open-source primary documents
Metternich et al (2013)	Thailand, 2001-2010 (insurgency or "anti-government actors")	lowest eigenvalue, latent space analysis	alliance, cohesion	network structure improves conflict level prediction; less cohesive movements produce more conflict	anti-regime group	cooperative acts	automated processing of event data from news stories
Pedahzur and Perliger (2006)	Palestinian suicide networks (terrorism)	centrality, density	hubs, scale-free, size	cohesive subgroups increases efficacy, more hubs equals more attacks	individual actor	kinship, friendship, acquaintance, reliability	press, org. internet sites and published documents, studies and articles
Rodríguez (2005)	11-M Madrid train bombings (terrorism)	degree distribution, centrality	cohesion, hubs, sub-groups, core-periphery	resiliency of sparse networks with an efficiency trade-off, removal of key nodes would weaken or destroy network	individual actor	kinship, friendship, co-habitation, meeting attendance, contact, reliability	press accounts from two Spanish newspapers
Zech (2010)	11-M Madrid train bombings (terrorism)	centrality, clustering, visualization, ERGMs	leadership, bridges, sub-groups, homophily, dynamic network	leadership bridges sub-groups, actors cluster by role, structure influences outcome	individual actor	communication, personal interaction, kinship	GTT database, court indictment, testimony, newspapers