Journal of Quantitative Criminology (2024) 40:33–74
https://doi.org/10.1007/s10940-022-09558-5

ORIGINAL PAPER

The Co-evolution of Friendship and Power Relations in a Men's Prison Unit

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Accepted: 10 September 2022 / Published online: 7 October 2022

Abstract

Objectives Despite renewed research interest in prison social organization, little is known about how relationships that constitute the prison social system develop and change. The current study aims to understand the processes that link friendship and power within a prison unit over time.
Method We examine longitudinal data on friendship and attributions of power collected from 274 residents in a Pennsylvania medium-security prison unit. We use a stochastic actor-oriented model to evaluate selection mechanisms that influence these relations and ascertain their temporal association.
Results We find different mechanisms responsible for friendship selections and power attributions. Friendships are primarily driven by attribute-based mechanisms, while power attributions are driven by network-based properties. Nevertheless, these two facets of social structure are interdependent, with friendships operating as building blocks for the development of power hierarchy in prison.
Conclusion By conceptualizing social structure as a multidimensional, fluid entity, we identify the unique roles that power and friendship relations play in recreating the prison social system. We maintain that understanding social structure in prison settings can provide insight into institutional adjustments and post-release expectations.

Keywords Friendship · Power · Longitudinal network analysis · Prison · Social order

Introduction

Inquiry into the nature of the "prison society" has a long-standing tradition through the ethnographic works of Clemmer (1958), Sykes (1958), Sykes and Messinger (1960), Irwin and Cressey (1962), and Jacobs (1977), among others. Embodying this line of thought, extant research has pointed to the collective nature of prison life, where residents are embedded in an evolving system of relationships that promote social cohesion and in-group

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identities while cultivating a system of deference and resultant hierarchy. Specifically, this work points to two fundamental dimensions of prison informal social structure that instill order and discipline: affective relations, such as alliances and friendship, and relations of deference that create power hierarchies. Affective relations develop because prisons are closed systems that constrain or sever relationships outside the prison, leaving residents to build connections within the prison to meet their ongoing social and emotional needs. Relations of power form as a means to maintain social order, facilitate cooperation, and manage relationships where formal order is lacking. This results in an informal system of power that enhances safety in exchange for deference to recognized peer leaders (Skarbek 2014; Trammell 2009) alongside friendships that meet one's needs for companionship, support, and identity reinforcement (Greer 2000; Kerley and Copes 2009; Wulf-Ludden 2013).

Over the last few decades, the expansion in the American prison population has resulted in changes in prison society (Kreager and Kruttschnitt 2018; Visher and Travis 2003; Wacquant 2001). Namely, a shift in goals from rehabilitation to punishment has increased the use of incarceration by the state, with high volumes of individuals cycling in and out of prison (Kreager and Kruttschnitt 2018; Wacquant 2001). This trend is pronounced, particularly affecting people from minority and socioeconomically disadvantaged communities (Irwin et al. 2000; Kreager and Kruttschnitt 2018; Vieraitis et al. 2007), leading to greater "fragmentation," "disorganization," and "unpredictability" in prison society (Hunt et al. 1993, p. 407; Wacquant 2001). For example, Wacquant (2001) argues that these changes have transfigured prison society, supplanting the convict code, formed to cope with the adverse effects of imprisonment and generate solidarity (Clemmer 1958; Irwin and Cressey 1962; Sykes 1958), with a value system that emphasizes "hypermasculine notions of honor, toughness, and coolness" (p. 110). These changes have also restructured the roles of residents vis-à-vis prison administration, with correctional staff enlisting residents in the task of maintaining social order by giving them various outlets of power and the autonomy to govern each other's behaviors (Crewe 2011; Skarbek 2014).

We argue that improving our understanding of prison informal social structure can offer insight into prison management, reentry, and post-release expectations. Namely, knowledge of prison social structure and processes to sustain it can inform efforts to maintain order and reduce conflict. First, correctional staff and residents depend on one another to maintain social order and preserve a safe and functional environment within the prison community (McDermott and King 1988; Sykes, 1958). Knowing how friendships develop and residents accrue power can be leveraged to improve institutional efficacy and inform strategies to minimize situational opportunities for antisocial behavior. For example, in their interviews with formerly incarcerated males, Trammell (2009) describes a "process of negotiation," whereby correctional staff compromise with residents and rely upon prison leaders to control violence. Similarly, Viggiani (2012) highlights instances where staff looked to prison leaders to provide "advice and protection," with officers noting, "if we want something sorted, we'll let him go ahead and sort it, so long as he don't assault no-one" (p. 281).

Second, knowledge of prison informal social structure can provide insight into how institutional adjustments and socialized behaviors can have long-term implications for post-release outcomes (Caputo-Levine 2013; Cochran et al. 2014; Martin 2018; Stuart and Miller 2017). For example, a long line of research has aligned prison experiences, specifically the convict code (Clemmer 1958; Irwin and Cressey 1962; Sykes 1958), with a set of subcultural beliefs, values, and behaviors that exist on the street (Anderson 1999; Mitchell et al. 2021). With high volumes of individuals cycling in and out of prison (Hughes et al.

2001; Vieraitis et al. 2007), habits developed to mitigate risk, survive, and cultivate relations in prison are likely to converge with street behaviors in a variety of ways. For example, elements of prison culture may contribute to upward mobility in the outside world. Stuart and Miller (2017) stress the importance of socialization and mentorship in prison for self-transformation post-release. In particular, they found that "prisonized old heads," who spent a lengthy period of time in prison, were instrumental to their neighborhoods upon release. These men drew on the "cultural repertoire" of prison life and their roles in prison to mentor young protégés in their neighborhoods.

Conversely, other prison experiences can pose difficulties for reintegration and desistance. Normative behaviors acquired to navigate power hierarchies (i.e., hypermasculinity and hypervigilance, isolation) and avoid exploitation (e.g., an unwillingness to smile or interact with strangers, institutional rule violations, and misconduct) can be detrimental to successful reentry, increasing risks of conflict in the community and a return to prison (Caputo-Levine 2013; Martin 2018; Visher and Travis 2003). Understanding how a resident's role in prison society (and that of their peers) shapes their behaviors on the inside and outside can improve the capacity of prison administrators and staff to leverage resources (e.g., programs, unit and cell assignments, treatment plans) that promote positive institutional adjustments and the likelihood of successful reentry.

We build upon research using social network imagery and methods to investigate informal prison structure (Haynie et al., 2018; Kreager et al. 2016a, b, 2017; Reid 2017; Schaefer et al. 2017; Schaefer and Kreager 2020; Young and Haynie 2022). We aim to identify the mechanisms by which power and friendship relations co-develop in prison. We consider these two relations jointly, given their inherent interdependence: power requires social relationships to create and support it (Magee and Galinsky 2008; Sauder et al. 2012; Torlò and Lomi 2017), and friendships are shaped, in part, by considerations regarding power in prison (Greer 2000; Pyrooz and Decker 2019; Trammell 2009). Nonetheless, these two types of relations differ in fundamental ways: friendships are egalitarian or "symmetric" relations characterized by affective motivations, whereas power is an imbalanced or "anti-symmetric" relation that serves instrumental purposes (Martin 2009). Therefore, we expect different processes to guide the development of each type of relationship.

The current study evaluates network selection mechanisms hypothesized to be responsible for change in informal prison social structure. We examine longitudinal data on friendships and power from a men's prison. We estimate the co-evolution of power and friendship with a stochastic actor-oriented model (Snijders et al. 2010). Our analysis focuses on identifying (1) the network selection rules guiding change in power and friendship relations, (2) whether the strength of selection mechanisms differs across networks, and (3) the association between power and friendship relations. Our results offer insight into the forces that sustain prison social structure and point toward friendship as a powerful substrate allowing hierarchies of power to emerge in prison.

Background

To understand relational development, it is important to consider that prisons are largely communal living spaces that provide little to no space for privacy or solitude. Apart from super-max institutions designed to eliminate (or minimize) social life and interactions, residents in the typical prison unit must share housing spaces and congregate in shared areas where contact is hard to avoid, and trust is difficult to establish (Jewkes 2005; van Hoven and Sibley, 2008). By housing individuals together while limiting their contact with the outside world, prisons are fertile ground for relationships, groups, and power hierarchies (Gaes et al. 2002; Priest and Sawyer 1967).

Relationships centered on friendship and power shape the prison experience in several ways. For some, friendships may be relatively pragmatic and superficial, cultivated to fill "dead time" and avoid feelings of isolation or loneliness (Crewe 2009; Liebling and Arnold 2012; Sykes 1958). For others, friendships may be centered on a desire for social support and self-improvement (Haynie et al., 2018; Kerley and Copes 2009; Severance 2005; Stuart and Miller, 2017; Wulf-Ludden 2013). While prison incites these dependencies, it poses inherent barriers as well. For example, relationships are limited to criminally sanctioned peers and those whose "experiences of trust tend not to dispose them to put faith in others" (Crewe 2011, p. 459; also see Young and Haynie 2022). Likewise, exchanges tend to be risky, cautious, and strategically driven (Crewe 2009; Liebling and Arnold 2012), making it harder to invest in and trust these relations (Kreager et al. 2016a, b; Lindquist 2000; Irwin and Cressey 1962; Sykes and Messinger 1960). These risks are especially pertinent for residents who want to avoid misconduct and victimization and those preparing for release, as they have little to no choice with whom they come into contact with (Bottoms 1999; McCorkle 1992).

Hierarchies of power are among the most pervasive features of social groups (Martin 2009).[1] Within prisons, power hierarchies facilitate social order and coordination among residents. In some cases, power use may be visible to observers, such as when aggression or violence is used to enforce order (Chase 1990). Other times, power use is not visible in discrete actions or behaviors, for example, manipulating the provision of rewards or punishments (Crewe 2009). Nevertheless, for hierarchy to emerge, there must be agreement regarding which individuals have power (Stadtfeld et al. 2020) and which do not (Magee and Galinsky 2008). Such awareness and acuity are especially salient within prison as failure to defer to those "at the top" may have long-term, often severe, consequences to the individual(s) and informal social organization.

We conceptualize friendship and power as distinct network relations. In the case of power, ties represent individuals' perceptions of who is powerful (see Magee and Galinsky 2008), which is distinct from the use of power in a dyad. In other words, we are interested in whether person *i* acknowledges or perceives person *j* as powerful, which we term a *power attribution*. With this definition, *i* may attribute power to *j* whether or not *j* has ever used power over *i*. This relational definition recognizes that power, in many circumstances, cannot be seized but is awarded by others through acts of deference (Ridgeway 2014; Sauder et al. 2012, p. 273). This relational approach to conceptualizing and measuring power has a productive history in studying social structure within children's classrooms (Coie et al. 1982; Bellmore et al. 2010; Newcomb and Bukowski 1983), workplaces (Labun et al. 2016), and, more recently, prison communities (Kreager et al. 2017, 2021). In the case of friendships, we conceptualize ties like other prison-based studies (Kreager et al. 2017; Schaefer et al. 2017). Notably, because some residents are averse to "friendships" in prison and are more likely to describe their close peers as "associates" (Crewe 2009; Kreager et al. 2016a, b), we ask residents to nominate peers with whom they "get along

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[1] The operationalization of "power" has a long intellectual tradition, leaving room for entanglements and ambiguities. While some have conceived power as pertaining to the attributes, values, and characteristic of persons engaged in such relations, others have conceived power as deriving from social relations. In either case, dyadic social interactions are expected to produce patterns of reciprocity and dependency indicative of the social and status order (Dahl, 1957; Emerson, 1962).

with most." These ties are symbolic of positive relationships whereby residents choose to spend time together. Like power, this definition is subjective; therefore, it is not uncommon for i to name j as someone they "get along with" while j does not name i in return. Although scholars have previously highlighted the importance of power and friendship in prison (Kreager et al. 2017; Schaefer et al. 2017; Skarbek 2014), no studies that we know of have directly examined how these relations operate in conjunction with one another across an entire prison unit (i.e., network co-evolution).

Selection Mechanisms

Our interest lies in understanding the systematic reasons why friendships and power attributions arise among some individuals but not others. Network scholars have identified several selection mechanisms responsible for the networks that structure daily life (Rivera et al. 2010; Wimmer and Lewis 2010). Below, we review those network selection mechanisms we argue are relevant to the development of power and friendship networks within prison. Unless otherwise stated, we expect the following mechanisms to operate for friendship and power attributions. Our empirical test measures the operation of these hypothesized mechanisms and evaluates their relative contribution to the evolving prison social structure we observe.

Attribute-Based Mechanisms (i.e., Individual Characteristics)

Attribute-related popularity Individual attributes are especially important for network selection processes. Within prison, gang members or individuals with a sophisticated criminal history (i.e., career-type criminals) may possess "hard power," exercised through coercion, intimidation, and violence (see Crewe 2009; Schrag 1954; Skarbek 2014). Other individuals may acquire "soft power" to negotiate relationships with staff and others (Crewe 2009; Crewe 2011; Trammell 2009; Viggiani 2012). For example, Kreager et al. (2017) highlighted the importance of age and tenure in shaping order. They found that older residents applied their maturity, age, and in-prison experience to stabilize informal social order in the unit. These individuals were able to "consolidate unit authority and socialize younger and more transitory peers toward prosocial attitudes and behaviors" (p. 687). Attributes such as these can also inform friend selection. Schaefer et al. (2017) found that longer-tenured residents in a prison unit were more likely than shorter-tenured residents to be selected as friends, which could be due to longer-tenured residents' better capacity to serve a mentoring role.

Homophily is the principle that relationships are more prevalent among individuals similar in attitudes, values, beliefs, and background (Lazarsfeld and Merton 1954; Marsden 1988). Attachment to like-minded peers simplifies communication (Ibarra 1992; Werner and Parmelee 1979), helping build rapport, solidarity, and trust (Felmlee et al. 1990; Kossinets and Watts 2009; Leenders 1996). Though earlier studies documenting homophily in informal networks come primarily from schools, workplaces, neighborhoods (McPherson et al. 2001), and co-offending populations (Carrington 2015; Charette and Papachristos 2017), more recent studies have considered prison settings. The heightened risk in prison settings means that residents must continuously assess how to maintain their security. A prominent way to mitigate risk and avoid misconduct is to seek individuals or groups who share one's identity and norms (Liebling and Arnold 2012; Pyrooz and Decker 2019). For example, commonalities based on race and religion drive residents to come together in time and place (i.e., prayer services, church, bible readings) while avoiding other areas, activities, or individuals (Liebling and Arnold 2012; McCorkle 1992; Skarbek 2014). Network studies of incarcerated males have found that friendships are more likely amongst those similar in age, race, religion, gang status, and prison tenure (Schaefer and Kreager 2020; Schaefer et al. 2017).

Homophily can also influence power attributions over time through multiple avenues. First, similarities make it easier to trust and understand others' motives. The behaviors of same-group members are more likely to be granted legitimacy, and their requests acquiesced to, compared to those of outgroup members. Second, the commonalities that drive social solidarity can lead to group formation while simultaneously creating tensions between groups (also see Trammell 2009). For example, Liebling and Arnold (2012) found that commonalities in race, ethnicity, and faith created an "us and them" mentality whereby in-group members accumulated power, status, and loyalty (p. 416). With either avenue, the consequence is that group divisions inhibit intergroup exchange, knowledge, and the repeated acts of deference needed to make attributions of power, leaving power to arise within homophilous groups. In line with this reasoning, prior prison-based network research has found homophily on race, ethnicity, age, tenure, and offense characteristics for various measures of power attributions.

Uniplex Network Mechanisms

The attribution of power or development of friendship within a dyad may depend on network connections outside the dyad. Network-based selection mechanisms ignore individual attributes and exclusively consider how some relationships promote other relationships. *Uniplex* mechanisms focus on a single type of relation (e.g., how one friendship may lead to another friendship). *Multiplex* mechanisms consider multiple types of relationships, such as how the pattern of ties among friends may affect who is perceived as powerful. We first describe uniplex network mechanisms, which are important controls and underlie the multiplex mechanisms that link power and friendship.

Sociometric popularity Actors with more incoming ties in a network exhibit "sociometric popularity." Such popularity promotes network change when people select peers who have already been disproportionately selected by others (Rivera et al. 2010, p. 103).[2] Popularity drives relationships because people rely upon others' relational behaviors and perceptions to inform their own (Walker 2016). This can occur if individuals are unable to detect others' signals of trustworthiness (Bacharach and Gambetta 2001) or if relationships carry risks, such as exploitation and violence (Liebling and Arnold 2012; Trammell 2009). Absent direct knowledge of trustworthiness, residents are likely to rely upon known and trusted residents (Kreager et al. 2017) or groups (Schaefer et al. 2017) to inform their perceptions (Colwell 2007; Schrag 1954). We expect sociometric popularity to drive both friendships and power attributions. Those who have proved themselves deserving of friendship will attract future friendships, and individuals will attribute power to peers whom others in their community have deemed powerful.

Reciprocity Reciprocal exchange of benefits is also a powerful means of building trust (Molm 2010). Reciprocal network relations, where an $i \rightarrow j$ tie is matched by an $i \leftarrow j$ tie,

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[2] This may be referred to as the "Matthew effect" (Merton 1968), "preferential attachment" (Newman 2001), or "cumulative advantage" (Price 1976).

represent one of the most common patterns found in friendship-type networks and coincide with emotional support, perceived closeness, and trust (Molm et al. 2007; Montoya and Insko 2008; Sprecher 1998, van de Bunt et al. 1999).[3] These needs are no less salient within a prison; reciprocity has been seen in cross-sectional studies (Schaefer et al. 2017). Hence, we expect to see reciprocity as prison-based friendships develop (Kerley and Copes 2009; Molm et al. 2007; Propper 1989).

In contrast to friendships, which emerge between "equals," power is asymmetrical and manifests between "unequals" (e.g., Gould 2002; Pastor et al. 2002; Propper 1989), symbolizing a hierarchical order (Chase 1990; Magee and Galinsky 2008; Martin 2009). For example, while deference to those in powerful positions can yield valuable benefits, powerful individuals have less incentive to reciprocate or reward deference with their own deference (Gould 2002; Schilke et al. 2015). In dominance relations, reciprocity tends to be rare and fleeting, reflecting a shift in the dominance structure (Chase 1990; Kreager et al. 2017; Schilke et al. 2015). Hence, we do not expect to observe reciprocity as a source of change in a network of power attributions.

Transitivity (i.e., closure) Transitivity occurs when indirect ties pave the way for a direct relationship (Rivera et al. 2010), such that the presence of $i \rightarrow j$ and $j \rightarrow k$ ties prompt the $i \rightarrow k$ tie. While transitivity produces more cohesive groups, it limits opportunities and exposure to new knowledge (Burt and Knez 1995). In high-risk contexts, including prisons, personal referrals can be critical for one's willingness to consider a relationship, specifically friendship (Clemmer 1958; Irwin and Cressey 1962). For example, a common friend may be able to "vouch" for that resident's reputation and trustworthiness; therefore, "a friend of a friend" may be seen as less threatening than a stranger, leading to a direct friendship (Wulf-Ludden 2013).

Transitivity has the same structural form in a power attribution network. However, its presence implies some degree of differentiation (Martin 2009). Drawing upon the above example, k is perceived as powerful by two others (i and j); j is perceived as powerful by one person (i), and i by none. Such a hierarchy may emerge because one person (i) bases judgments of power on whom powerful others (e.g., j) defer to (in this case, k). Transitivity in a power attribution network is consistent with findings that those on the outskirts of the "group" perceive those on the inside as powerful. In contrast, group members (i.e., those on the inside) can more finely differentiate roles amongst one another (Kreager et al. 2017; Pyrooz and Decker, 2019).

Multiplex Network Mechanisms (i.e., Cross-Network Effects)

A major question driving this research is how much do friendships beget power attributions versus perceptions of power motivating friendship in prison. Network research has demonstrated an association between power attributions and friendship in prison (Kreager et al. 2017; Schaefer et al. 2017) but has not investigated their temporal ordering. We expect power attributions and friendship to be connected in a myriad of ways described below. Given the complexity of multiplex selection, we illustrate these mechanisms in Fig. 1 (where we also provide details relevant to our analysis). Although we are considering change in multiple networks (i.e., friendship, power), when conceptualizing a specific

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[3] We use the $i\ j$ notation to denote that person i named person j in the respective network (i.e., as a friend or as someone powerful).

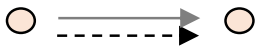
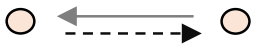
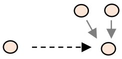
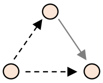
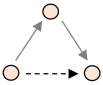
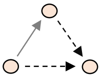
Effect Name	ShortName	Diagram	Equation
(a) entrainment (i.e., main cross-network effect)	crprod		$\Sigma_j x_{ij} w_{ij}$
(b) reciprocity	crprodRecip		$\Sigma_j x_{ij} w_{ji}$
(c) popularity - indegree	inPopInt		$\Sigma_j x_{ij}(w_{+j} - \overline{w})$
(d) transitivity			
XWX - closure	cl.xwx		$\Sigma_{j\neq h} x_{ij} x_{ih} w_{hj}$
closure	closure		$\Sigma_{j\neq h} x_{ij} w_{ih} w_{hj}$
to	to		$\Sigma_{j\neq h} x_{ij} w_{ih} x_{hj}$
Dependent network (x) - - - -► **Independent network** (w) ⟶			

Fig. 1 Cross-network (Multiplex) Effects for the "Get Along With" (i.e., Friendship Nominations) Network and Power and Influence (i.e., Power Attributions) Network. *Note* Dashed lines represent the network being considered in a given selection decision, whereas solid lines represent the other network and are exogenous. Our analysis assumes network change follows a Markov process in which only one tie can change at any time. Hence, for the *XWX-closure* effect, either dashed line would create transitivity, assuming the other dashed line is present. For the *to* effect, only the lower dashed line (i.e., the *i,j* tie) is being considered for change, with the other dashed line presumed to be present already. An extensive description of multiplex network effects and their corresponding fuctions are available in the Manual for RSiena by Ripley et al. (2019, pp.154–161). Standard effect names, refered to as "shortNames," are used to identify effects in the RSiena package

change mechanism, we focus on change in one network (denoted *X*) conditioned on the other, explanatory network (denoted *W*).

Entrainment represents how one type of relation (e.g., friendship) facilitates another type of relation (e.g., power attribution) between the same two persons. Entrainment considers the effect of *W* on *X*, where $i \overset{W}{\to} j$ leads to $i \overset{X}{\to} j$ (shown in Fig. 1a). In other words, *i* naming *j* in network *W* increases the likelihood that *i* will also name *j* in network *X*. We expect to find entrainment in both directions when examining power attributions and friendship. Friendship allows for the development of trust and an understanding of others' motives, leading to deference. Alternatively, perceiving someone as powerful may provide the motivation to befriend the person. In return, powerful allies can provide greater access to resources, opportunities, and other advantages over peers (Benjamin and Podolny 1999; Labun et al. 2016). Instead of befriending or deferring to strangers, residents can reduce uncertainty and ensure protection from victimization by "bundling" their relationships (Kadushin 2012). Hence, entrainment can add to the depth of a relationship. This effect is consistent with Kreager et al. (2017), whose cross-sectional study found that residents were more likely to nominate as powerful those residents with whom they get along with.

Reciprocity can operate in a multiplex fashion across networks. As shown in Fig. 1b, multiplex reciprocity considers the effect of an incoming W tie on an outgoing X tie (i.e., $i \overset{W}{\leftarrow} j$ leads to $i \overset{X}{\rightarrow} j$). Here, an existing tie in network W prompts a return tie in network X. Examples of this process can be found in work settings where, for example, individuals reciprocate advice by granting power (Blau 1964), reciprocate power with friendship (Labun et al. 2016), and befriend those who they share gossip with (Ellwardt et al. 2012). While this question has not been tested directly in previous prison network studies, it can be observed in a study by Stuart and Miller (2017), finding that upon re-entry, "prisonized old heads" served as informal mentors in poor urban neighborhoods. In return, their provisions of social support and mentorship were rewarded with deference on the street. Similarly, we expect residents to befriend others who see them as powerful or respond to another's friendship with power attributions in a prison setting.

Popularity considers whether incoming ties in one network (W) enhance one's tendency to be named in another network (X). Specifically, popularity—indegree (inPopInt), shown in Fig. 1c, considers the effect of someone's indegree in W on their subsequent indegree in X. As shown in Fig. 1c, multiplex popularity differs from entrainment in that it is ties to j from others, not i, in W that predict the $i \overset{X}{\rightarrow} j$ tie. For example, residents may be inclined to befriend those whom others perceive as occupying an elevated position of power, intending to cultivate the benefits and social status such ties may yield (Coleman 1988; Newman 2001; Price 1976). Likewise, those more embedded in the friendship network may be perceived as more influential and hence be attributed with power by others (i.e., individuals perceive peers with many friends as powerful).

Finally, *transitivity* may operate to create closure across multiple networks. Transitivity signals an alignment of ties between three individuals; cross-network transitivity signals friendship alliances while recognizing hierarchal structure within the group (Labianca and Brass 2006; Stadtfeld et al. 2020). For example, Labun et al. (2016) found one form of cross-network transitivity in the workplace, where employees who named someone as powerful were also likely to name that person's friends as powerful. We expect that shared perceptions of others within prison will drive relationship development (Crewe 2009; Skarbek 2014). This can take many forms, as we show in Fig. 1d. First, individuals may rely upon their friends' assessments of who is powerful when making their evaluations. This is represented by the "to" effect, whereby the $i \overset{W}{\rightarrow} h \overset{X}{\rightarrow} j$ mixed two-path leads to the $i \overset{X}{\rightarrow} j$ tie. Second, friends of people perceived as powerful may also be regarded as powerful. This can be seen in the "XWX closure" effect, where an $i \overset{X}{\rightarrow} j$ tie is dependent on an $i \overset{X}{\rightarrow} h \overset{W}{\rightarrow} j$ mixed two-path.[4] A third version of transitivity occurs when individuals befriend the friends of those they perceive as powerful, such as boosting their status or gaining protection. This is represented by the "closure" effect, where the number of $i \overset{W}{\rightarrow} h \overset{W}{\rightarrow} j$ two-paths affects the likelihood of an $i \overset{X}{\rightarrow} j$ tie.

Current Study

The current study tests mechanisms hypothesized to drive the co-evolution of friendship and power attributions within prison. We focus on the same context and empirical data as cross-sectional studies of power (Kreager et al. 2017) and friendship (Schaefer et al. 2017). However, by taking a longitudinal perspective, we can address a larger set of questions.

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[4] Another interpretation of this effect is $i \overset{X}{\rightarrow} j$ tie is dependent on the number of $i \overset{X}{\rightarrow} h \overset{W}{\rightarrow} j$ mixed in-stars.

First, our primary questions are which hypothesized network selection mechanisms explain friendship and power attributions? Second, how does the strength of these selection mechanisms differ across the two networks? Are some more important for one type of relation than others? Third, what is the nature of the bidirectional pathway linking power attributions and friendship over a period of time? Are selection effects stronger in one direction than the other, and how does their magnitude compare to other selection mechanisms? Although we expect many of the same relational mechanisms to be operational within power and friendship networks, their relative strengths will likely differ. By evaluating these relational mechanisms, we shed light on social structure within one prison society.

Data and Methods

Sample

Data come from the Prison Inmate Network Study (PINS), which centered on a medium-security Pennsylvania men's prison (Kreager et al. 2017; Schaefer et al. 2017; Haynie et al. 2018). We focus on a "good behavior" (Custody 2) housing unit designated by the Pennsylvania Department of Corrections for those who have demonstrated non-aggressive behavior, showed good behavior for the six months before their entry, and remain misconduct-free while on the unit. The unit houses approximately 200 men and is physically segregated from the rest of the prison population. However, residents can associate with others during their free time (e.g., mealtime, yard time) and when attending programs or school. Data were obtained from two sources. First, self-report surveys were administered through face-to-face interviews using a Computer-Assisted Personal Interview protocol. Interviews with 179 residents were conducted at two time points approximately five months apart. Second, the Pennsylvania Department of Corrections (PADOC) provided administrative data for all residents on the unit.

Measures

Network Data The survey asked about interpersonal relations within the unit during two time points. *Friendship ties* were captured by asking residents who they "get along with most" in the unit. *Power attributions* were captured by asking residents who they perceived as "the most powerful and influential in the unit." For each type of relation, residents were provided a comprehensive roster of all current residents on the unit, establishing clear network boundaries. Notably, residents could nominate as many fellow residents as they wanted, and all residents could be named a friend or attributed with power. To add context to the meaning of power in the unit, almost 70% of wave 1 residents attributed power and influence to prosocial qualities, including prison wisdom ("*he has an understanding of how everything runs"*), sociability traits ("*he is very charismatic"*), mentorship qualities (*he gives good advice*" or *"he mediates between guys"*), and intelligence ("*smart guy"* or *"Avid reader, well-educated"*) (Kreager et al. 2017, p. 697).

Table 1 provides the structural properties of each network in waves 1 and 2. On average, residents were named 2.8 times in the friendship network and 0.8 times in the power network (i.e., average indegree). Among the subset of residents, the average number of nominations made (i.e., average outdegree) was 4.7 in the friendship networks and 1.1 in the power network. Overall, 23.5% of friendships were reciprocated, but only 2.5% of

Table 1 Description of the "Get Along With" Network (i.e., Friendship Nominations) and Power and Influence Network (i.e., Power Attributions)

"Get Along With" Network (i.e., Friendship Nominations)	Wave 1 (n = 205)	Wave 2 (n = 207)
Number of ties	696	474
Indegree average[a]	3.40 (SD = 2.83)	2.29 (SD = 2.07)
Indegree range	0–13	0–12
Outdegree average[b]	5.23 (SD = 4.70)	4.16 (SD = 3.75)
Outdegree range	0–22	0–20
Reciprocity	0.23	0.24
Transitivity	0.15	0.16
Centralization (degree)	0.07	0.05
Largest connected component (size)	191	183
Jaccard Index (n = 138)[c]	0.28	
Power and Influence Network (i.e., Power Attributions)	**Wave 1 (n = 205)**	**Wave 2 (n = 207)**
Number of ties	151	157
Indegree average[a]	0.74 (SD = 2.25)	0.76 (SD = 1.91)
Indegree range	0–13	0–13
Outdegree average[b]	1.14 (SD = 1.56)	0.96 (SD = 1.67)
Outdegree range	0–9	0–7
Reciprocity	0.01	0.04
Transitivity	0.19	0.20
Centralization (degree)	0.03	0.04
Largest connected component (size)	91	82
Jaccard Index (n = 138)[c]	0.25	

Reciprocity indicates the fraction of ties that are reciprocated. Transitivity is a proxy for social closure, measuring the proportion of indirect ties that are closed by a direct tie

[a] Because all unit residents could be nominated (including non-respondents), the average indegree centrality considers all residents on the unit (wave 1 = 205; wave 2 = 207) and excludes self-nominations

[b] The average outdegree centrality considers survey responses from eligible respondents (wave 1 = 133; wave 2 = 114) and excludes self-nominations

[c] The Jaccard Index was limited to residents that were present in both waves (n = 138)

power nominations were reciprocated. Social closure was more operative in the power network, with approximately 19.5% of power attributions displaying transitivity compared to 15.5% in the friendship network. These structural differences between the friendship and power networks are expected, underlining substantive differences between friendship and power attributions. Namely, friendships are used to cope with prisonization and are characterized by mutual feelings of closeness and social support (Crewe 2009; Severance 2005; Sykes 1958), whereas power attributions coincide with deference and are often asymmetric (Kreager et al. 2017; Schilke et al. 2015). The Jaccard index indicates that of the ties present in either wave, about a quarter were present at both waves (28% of friendships and 25% of power perceptions). This level of stability meets the threshold of 20% recommended for model estimation (Snijders et al. 2010).

Table 2 Descriptive statistics

	Unit—Wave 1 (n=205)				Unit—Wave 2 (n=207)				Unit—Wave 1 and Wave 2 (n=274)				
	% or mean	SD	Min	Max	% or mean	SD	Min	Max	% or mean	SD	Min	Max	Mean Similarity[a]
Age	39.47	11.14	21	72	39.41	11.23	21.13	71.83	38.86	10.91	21	72	0.757
Years in prison	8.01	7.53	0.36	44.98	7.41	7.65	0.78	45.23	7.14	7.04	0.36	45.23	0.849
Years on unit	1.41	2.23	0.01	14.16	1.42	2.27	0.01	14.53	1.28	2.06	0.01	14.53	0.889
Offense gravity score	9.99	3.37	1	18	9.75	3.32	1	18	9.60	3.34	1	18	0.787
Gang or STG	0.06	0.24	0	1	0.05	0.23	0	1	0.06	0.23	0	1	0.890
Program participation	1.83	1.46	0	6	0.46	0.72	0	4	1.57	1.41	0	6	0.746
Race/Ethnicity													
White/Other	39.02		0	1	39.22		0	1	38.46		0	1	
Black	46.83		0	1	48.53		0	1	49.45		0	1	
Hispanic	14.15		0	1	12.25		0	1	12.09		0	1	
Religion													
Muslim	21.46		0	1	22.50		0	1	23.05		0	1	
Catholic	18.54		0	1	16.50		0	1	15.61		0	1	
Protestant	20.49		0	1	25.00		0	1	23.79		0	1	
Other religion	24.39		0	1	24.50		0	1	23.79		0	1	
No religion	15.12		0	1	11.50		0	6	13.75		0	1	

SD standard deviation, *STG* security threat group

[a] Mean similarity is a dyadic level transformation of the absolute difference between actor scores in each dyad (see Ripley et al. 2019). Dyadic similarity ranges from 0, indicating two individuals are maximally dissimilar, to 1, indicating identical scores. This statistic is only meaningful for continuous measures

[b] Rates of missingness were less than 2% on all covariates

Attributes Table 2 summarizes the sociodemographic characteristics of the men on the unit. Unless otherwise specified, measures were provided by PADOC. *Race/ethnicity* and *religion* are categorical measures based on self-reports during prison intake. The unit was racially/ethnically diverse (primarily Black and White) at both time points and housed residents with various religious affiliations. *Years in prison* measures the total number of years incarcerated in state prison. In contrast, *years on the unit* measures the total number of years the respondent has spent on the specific housing unit. On average, residents spent seven years in prison (SD = 7.04) but 1.28 years on the unit (SD = 2.06). Resident *age* ranged from 21 to 72 years old, with a mean of 38.9 (SD = 10.91). Given their distributions, these measures were logged before analyses.

Security Threat Group (STG) classifications were designated during prison intake based on self-admissions, court records, associations, tattoos, or law enforcement intel. For analysis purposes, we combine STG classifications with self-reports of gang membership. Overall, 6% of residents reported current or prior gang involvement. The *offense severity score* is a continuous measure representing the severity of the offense for which they are currently incarcerated. Offense severity scores amongst the population range from 1, which is least (e.g., misdemeanor), to 18, which is most severe (e.g., 1st-degree murder), with a mean of 9.6 (SD = 3.34). *Program participation* is a count derived from responses to the question, "What organized religious or social groups are you now participating in? These could include education classes, religious services, or something else". On average, residents participated in 1.57 (SD = 1.41) programs, ranging from 0 to 6 services. Finally, responses for *city* come from the survey question, "In what city and state were you living before this prison stay?".

Analytical Strategy

We use a stochastic actor-oriented model (SAOM) to examine how friendship and power attributions coevolve. The SAOM is a model of longitudinal network change that predicts which relationships form or persist across time (see Snijders 2001; Snijders and Pickup 2017; Snijders et al. 2010). While most criminological applications of SAOMs have aimed to disentangle selection and influence effects (Duxbury and Haynie 2020; McMillan et al. 2018; Ragan 2020), SAOMs can also be specified to exclusively model network dynamics (Schaefer 2018; Schaefer and Kreager 2020). Our study builds on the latter approach by simultaneously estimating change in multiple networks over five months (Labun et al. 2016; Snijders et al. 2013). In our specification, both power attributions and friendship are incorporated as dependent networks; therefore, changes in the friendship network are conditional on changes in the power network and vice versa. Given the nature of our study, this is not a causal analysis. Instead, the SAOM establishes the temporal ordering that links power attributions with friendships for those dyads where the state of one type of relation changed across observations (Snijders and Pickup 2017). Namely, we can determine how often friends later attributed power to one another and how often dyads characterized by a power attribution later developed into a friendship.

For the analysis, the friendship and power networks were each specified as a 274 × 274 matrix (x) for each time point (resulting in four matrices). For a given type of relation and time point, cell i,j represents whether the person listed in row i named the person in column j (e.g., as someone powerful or with whom they get along with). Cells representing each ordered dyad are coded “1” if *i* named *j* for that type of relation, and “0” otherwise. The matrices included all 274 residents housed on the unit at either time.[5] For residents who were not housed on the unit at a given time point, we coded the cells in their rows and columns in the power and friendship matrices as a “structural zero,” and they were omitted from analyses at that wave (i.e., unit turnover). For residents who were housed on the unit but did not complete the survey at a given time point, we coded their corresponding rows of the power and friendship matrices as missing (i.e., non-respondents/ ineligible residents).[6] This allowed for model-based imputation of their ties (Huisman and Steglich 2008). Column values associated with non-respondents were not necessarily missing since respondents could have named them as someone powerful or with whom they get along with.

Though the power and friendship networks were each observed at two discrete times, the SAOM assumes change occurs in continuous time through a sequence of micro steps that constitutes a Markov process, whereby network ties change one by one, with each change dependent only on the current state of each network. The SAOM assumes that actors control their outgoing ties; hence, during each micro-step, one actor is given the chance to change a tie in the friendship or power network. Decisions are informed by utility functions, described below, that specify the hypothesized selection mechanisms. The goal of model-fitting is to obtain parameter estimates corresponding to each selection mechanism that allow the model to recreate the networks observed at time 2.

Estimation is achieved via an MCMC algorithm implemented as an actor-based simulation. The model conditions on the networks observed at time 1. Then, during each micro step, a randomly chosen actor is given the opportunity to change one tie in one network, either by forming a new tie or dropping an existing tie (or possibly making no change). A rate function for each network specifies how often change occurs. We specified a uniform rate function that gave all actors the same chance of being chosen to make a change. The estimated rate parameters gave actors approximately twice as many opportunities to change friendship ties compared to power ties.

Selection functions for each network determine *which* tie is changed during a micro-step. The friendship and power functions take the same general form: a conditional logit discrete choice model that considers the probabilities of tie creation and maintenance over time, as shown below.

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(x) \tag{1}$$

In Eq. (1), the value $fi(\beta, x)$ is the evaluated “utility” of a potential network state for actor (i) as determined by the (k) effects ($s_{ki}(x)$) included in the model and weighted by the current set of corresponding parameter estimates (β_k). Effects are based on the current

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[5] A total of twelve residents in wave 1 and eight residents in wave 2 were considered ineligible to participate in the survey given that a mental health designation (d-code) in their correctional file raised concerns about their capacity to consent to the study. We exclude these residents’ responses from the network portion of the survey, coding their outgoing ties as missing (“NA”), but kept their incoming ties (e.g., measure of indegree), which were elicited from eligible respondents.

[6] Of the 274 residents on the unit at either observation wave: at wave 1, 12 were ineligible given their mental health designation, 133 were eligible to participate and responded to the survey, 60 did not respond to the survey, and 69 were not yet on the unit; at wave 2, 8 were ineligible given their mental health designation, 114 were eligible to participate and responded to the survey, 85 did not respond, and 67 had left the unit.

network state (x) and can incorporate information on individual attributes and other relations (Schaefer 2018, p. 287; Snijders et al. 2010, p. 47). During a micro-step, the chosen actor i calculates the value of the selection function for every possible change—for dyads *i,j* where no tie exists, this is the value after creating the tie; for ties *i,j* that exist, this is the value after dissolving the tie. The actor then compares the value of each possible change and the value if no change is made and makes the choice that offers the highest value.[7] At this point, the micro-step ends, and the process repeats.[8] This process continues until the model reaches convergence, defined as the model being able to reproduce simulated networks whose distributions of summary statistics are centered on the observed statistics (Ripley et al. 2019).

We now turn to model specification, described using standard effect names, called "shortNames" in the RSiena package and detailed by Ripley et al. (2019). The friendship and power functions include the *rate* and *outdegree* effects mentioned above that are not of substantive interest but are required for model estimation. Several additional effects predict which ties are more likely to form or persist across time. Effects are included in both the friendship and power functions unless otherwise specified. For more on these effects, see Appendix A, which provides pictorial representations, equations (used as summary statistics), and the RSiena shortName.

Attribute-based mechanisms (i.e., covariate effects) model how network changes are dependent on the characteristics of the person being named (*alter*), the focal actor sending the tie (*ego*), or the similarity between ego and alter (*similarity* for continuous attributes and *same* for categorical attributes). These effects represent age, years on the unit, offense severity, gang/STG status, race/ethnicity, religion, and city. To illustrate how these effects operate within the model, consider the *same* effect for race/ethnicity, operationalized as $\Sigma_j x_{ij} I(v_i = v_j)$, where $I = 1$ if $(v_i = v_j)$ and $I = 0$ otherwise. Assume this effect has a positive parameter estimate of 0.5 in the friendship function. When actor i is evaluating every possible change, dyads where i and j share the same race/ethnicity (v) will produce a 1 on this statistic, which is multiplied by 0.5 and contributes 0.5 to the friendship evaluation function. A dyad where i and j differ in race/ethnicity will produce a 0 on this statistic, which is multiplied by 0.5 and contributes 0 to the friendship evaluation function. In this scenario, dyads, where two individuals share the same versus different race/ethnicity, will produce a higher evaluation of the friendship selection function, with such relationships more likely to be created or maintained, all else being equal.

Uniplex network effects capture how change in a focal dyad depends upon relationships in other dyads, all within the same network. For example, *popularity—indegree* measures the extent to which individuals with more incoming ties are more likely to receive

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[7] A small amount of error is added to each evaluation to ensure stochasticity.

[8] A single "chain" begins with the observed networks at time 1 and proceeds through thousands, if not more, micro-steps. The number of micro-steps in a chain is determined by the estimated rate parameters for each function and is a function of the Manhattan difference between the time 1 and 2 networks. Once a chain has completed, the resulting networks are compared to the observed networks at time 2 using summary statistics representing each modeled effect in the power and friendship networks at time 2 (i.e., method of moments). For example, the *outdegree* effect ($\sum_j x_{ij}$) calculates the number of ties in a network. At the conclusion of a chain, the number of ties in each simulated network is compared to the observed outdegree in the power and friendship networks at time 2. Depending on the nature of the discrepancy between simulated and observed counts, the parameters for outdegree in each function will be adjusted prior to simulating the next chain (e.g., if simulated friendship outdegree is too low, then the friendship outdegree parameter is raised). This comparison is made across all model statistics and all model parameters updated.

additional ties. We also specify *reciprocity*, *transitive triplets,* and their interaction (*transitive reciprocated triplets*). Additional uniplex effects, while not substantively interesting, help improve model fit by better representing degree distributions (Snijders et al. 2010). These include o*utdegree—activity*, which measures the extent to which residents who currently nominate many others continue doing so, and *popularity—outdegree*, which measures the extent to which ties sent contribute to the probability that residents become or remain receivers of ties. Failure to include these effects would overestimate the effects of attributes on receiving and sending ties (Lusher and Ackland 2011).

Considering our main aims, we include cross-network (i.e., multiplex) effects representing dependencies between the friendship and power networks. These include (1) *entrainment*, the main cross-network effect that measures the effect of each type of tie on the other, (2) *reciprocity,* (2) *popularity—indegree*, and (4) *transitivity.* Because cross-network transitivity can operate in multiple ways, we explore three forms (*to, closure, XWX-closure)* that convey slightly different theoretical mechanisms (see Fig. 1). Due to multicollinearity, we tested these three specifications separately using a score-type test to evaluate whether adding an effect is expected to improve overall model fit (Schweinberger 2012; Ripley et al. 2019). We included any effects with a significant score test in our final set of models. We tested these cross-network effects in both functions. Within each respective function, the dependent network is denoted x and the predictor network as w. During a given micro step, the chosen actor considers changes to only one network, x, while the other network, w, is held at its current state.[9] We follow recommended procedures and levels for model fitting and convergence (Snijders et al. 2010). All t-ratios for convergence were less than 0.10, and the overall maximum convergence ratio was less than 0.25. The goodness of fit test also demonstrates that the model fits well (see Appendix B). Models were estimated using the RSiena package (version 1.2; Ripley et al. 2019) within the R software for statistical computing (R Core Team 2018).

Our final step was to calculate the *Relative Importance* (RI) of estimated effects (Indlekofer and Brandes 2013). The RI measure was developed in the spirit of standardized effects in a regression model to allow comparisons of effect magnitudes within and between fitted models. RI scores are calculated by applying a fitted SAOM to an observed network and evaluating how the cumulative distribution of tie choice decision probabilities across all actors would differ with each respective parameter held at its estimated value versus constrained to 0 (Indlekofer and Brandes 2013). RI scores range from 0 to 1 and sum to 1 across all effects in a function. We aggregate RI scores across effects of the same type to estimate how much selection decisions in each network could be attributed to each class of selection mechanism. For example, if power attributions were predicted by friendship and no other mechanism, the RI of friendship on power would be high (maximally 1). If there were no effect of power on friendship, the RI of power effects in the friendship function would be low (minimally 0) (Indlekofer and Brandes 2013).

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[9] To differentiate the directionality linking the two networks, the summary statistics representing these effects use the time 1 observation of w and the time 2 observation of x. For instance, the *entrainment* effect ($\Sigma_j x_{ij} w_{ij}$) predicts the x_{ij} tie based on the presence of a w_{ij} tie. Hence, the entrainment summary statistic for the effect of power on friendship is calculated as the number of dyads with both a time 1 power attribution and time 2 friendship, while the summary statistic for the effect of friendship on power uses the number of dyads with a time 2 power attribution and time 1 friendship.

Results

Unit Turnover and Non-Response

The observed unit housed just over 200 residents at each wave but experienced a good deal of turnover between observations. One-quarter of wave 1 residents left the unit by wave 2 (n = 67), and 69 new residents joined the unit. Thus, only 138 residents were on the unit during both observation periods. To offer insight into how turnover is related to the social positions of residents, we compared continuous residents to those who joined or departed the unit between waves (Appendix C). At wave 1, residents about to leave the unit were less integrated than continuous residents, receiving fewer friendship nominations and power attributions (though the difference for power was not significant; $p = 0.107$). Likewise, new residents in wave 2 were less integrated into both networks, receiving significantly fewer friendship nominations and power attributions than those who continued following wave 1. These differences suggest that, despite the unit population being in constant flux, informal structure changes more slowly as network ties are concentrated among residents who persisted on the unit.

We completed at least one interview with 179 (65%) of the 274 residents on the unit at either wave, 68 of which were from the 138 residents on the unit at both waves (49%). Although the SAOM can accommodate some level of unit turnover (i.e., composition change) and missing data (i.e., non-responses), it is important to understand the nature of missingness. In our study, a resident may not have completed a survey in a given wave because: (1) they were not housed on the unit during the wave (i.e., unit turnover), (2) they did not complete the survey (i.e., non-respondents), or (3) they were not eligible to participate given their mental health designation (i.e., ineligible residents). The first source (unit turnover) is not considered missingness as these residents were not part of the unit at the respective wave and hence not part of the unit's social structure as we define it. The remaining sources are considered missing and deserve deeper inquiry into whether these residents' attributes and network position substantively differ. Because we have PADOC data on all 274 residents, we can compare the attributes of respondents to those who did not complete the survey or were ineligible to participate (Appendix D). We find minimal differences between the two subsamples across the waves. However, we observe notable differences in network patterns based on response status. At both waves, non-respondents/ineligible residents received significantly fewer friendship nominations and power attributions than respondents. That is, non-respondents/ineligible residents were noticeably less integrated into the informal social structure of the unit. This is consistent with Watanabe et al. (2017), who argue that socially isolated individuals are less likely to respond to surveys than those more embedded and central to the network.

SAOM Results

Next, we estimate a sequence of models containing all attribute and univariate effects but sequentially test the cross-network effects. Model 1 serves as our baseline model, examining the predictors of friendship and power in the absence of cross-network effects. The second model draws attention to the co-evolution of friendship and power in prison (and vice versa) by introducing a single cross-network structural effect (*entrainment*). Finally, models 3–5 specify additional cross-network dependencies, tested separately due to potential

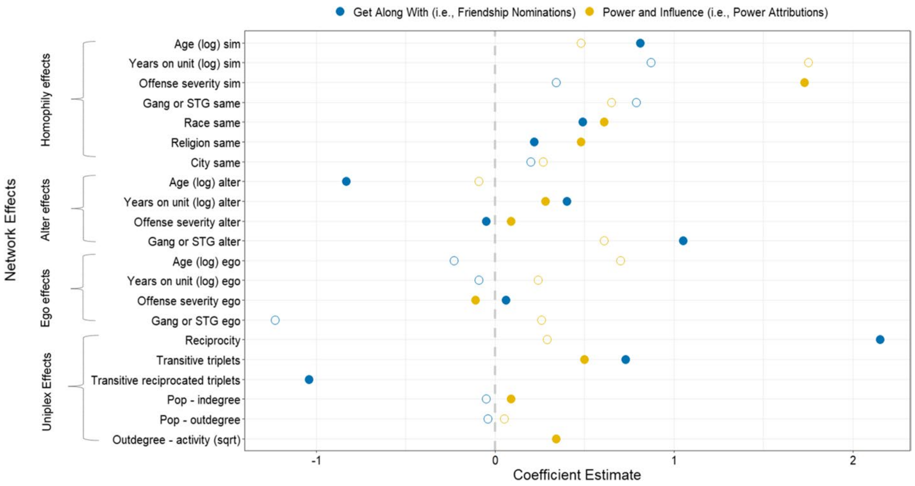

Fig. 2 Estimates from the Stochastic Actor-Oriented Model for the Baseline Model, Model 1. *Note* Solid circles represent effects that are significant, or marginally significant, at p < 0.10. For visualization purposes, rate and outdegree effects are omitted. The rate and outdegree estimates are 13.40 (SE = 1.16) and -3.61 (SE = 0.57), respectively, for the friendship network and 5.68 (SE = 0.98) and -5.92 (SE = 0.78) for the power and influence network

collinearity, and Model 6 is our full model. Full results for each model are reported in Appendix E.[10]

We begin by describing the results for our baseline model (shown in Fig. 2). Results for attribute-based mechanisms indicate that homophily and attribute-based popularity were present across networks but in different ways. Selection based on race and religion homophily was evident in both networks. However, the latter effect was only significant at $p < 0.10$ in the friendship network. Homophily effects were significant for other attributes, although their interpretation is complicated by significant ego and alter effects. To interpret these effects, we calculate the predicted contribution to the log-odds of a tie for the range of ego-alter attribute combinations (Snijders et al. 2010).[11] Figure 3 shows a heatplot of the predicted contribution to the selection function (i.e., likelihood of a tie) based on each possible combination of ego and alter attributes for (a) age in the friendship network and (b) offense severity in the power network. The x-axis corresponds to ego's attribute value, and the y-axis corresponds to the attribute of their prospective target. The colors specify the magnitude of the predicted contribution to the conditional log-odds of a tie for a given ego and alter scores on the attribute. For example, the positive similarity effect for age indicates that residents were more likely to befriend peers who were similar in age, but this is offset by the negative age alter effect. In combination, younger residents were more strongly driven to select similar friends, with older residents indifferent to friend age (net of other

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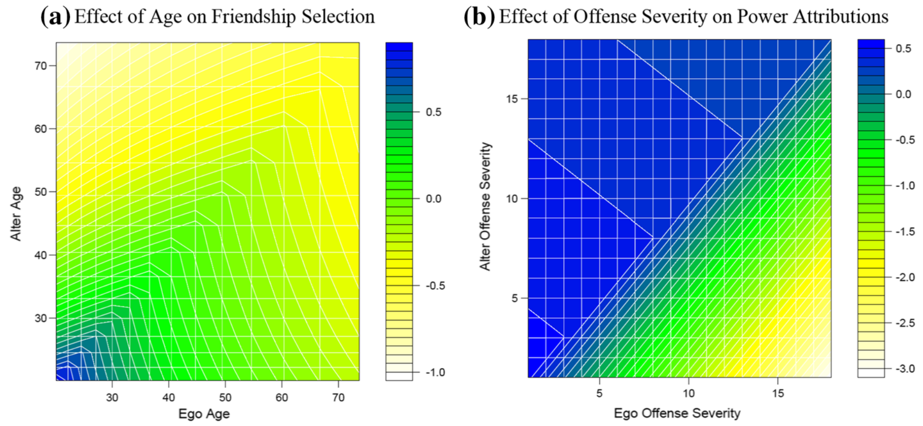
[10] We evaluated covariate effects for years in prison, program involvement, and state of residence, which prior studies found to impact friendship and power attributions. However, a series of score tests determined that these covariates did not improve model fit. Electing for a parsimonious model, these effects were excluded, which also helps preserve power.

[11] Parameter estimates can be interpreted in terms of the expected effect of a one-unit change on the log odds of a tie. Exponentiating a parameter estimate gives the difference in odds of a tie in two hypothetical dyads that differ by one-unit on the independent variable, assuming all else is equal.


(a) Effect of Age on Friendship Selection

(b) Effect of Offense Severity on Power Attributions

Fig. 3 Heatplot of the ego-alter selection table for Age in the "Get Along With" (i.e., Friendship Nominations) Network (left) and Offense Severity in the Power and Influence (i.e., Power Attributions) Network (right). *Note* The y-axis corresponds to ego's age or offense severity, and the x-axis to alter's age or offense severity. The colors specify the relative gain to ego's objective function when selecting alters across various ages (range: 21–72) and offense severity levels (range: 1–18). Higher (darker) values correspond to a greater likelihood of selection, all else being equal

selection processes in the model). Within the power network, selection based on offense severity was present. However, the significant ego and alter effects outweigh this; therefore, residents were most likely to make power attributions to those whose offense severity was equal to or greater than their own. We do not find evidence of homophilous selection on other attributes in either network.

Alter effects pertaining to attributes offer insight into differences in resident popularity. Positive effects for unit tenure and gang/STG status indicate that residents were more likely to be named in the friendship network if they had been on the unit longer or were gang/STG-involved ($p < 0.10$). The negative effect for offense severity combined with the positive ego effect indicates that residents with more severe offenses were more likely to name friends than residents with less serious offenses but less likely to be named as a friend. Lastly, a marginally significant effect of alter years on the unit indicates that longer-tenured residents may have been more likely to be perceived as powerful. This effect is consistent with the finding that prison "old heads" carry greater power (Kreager et al. 2017).

Next, the uniplex network effects reveal different selection mechanisms in the two networks. In the friendship function, we observe the positive effects of reciprocity and transitivity and their negative interaction. These results were expected given the long line of research on friendship networks and, in combination, suggest that friendships were more likely if they were supported by reciprocity or transitivity. However, these effects are not entirely additive (Block and Grund 2014). We do not find the effects of sociometric popularity on friendship. Turning to the power network, reciprocity had no effect as expected. In contrast, transitivity had a marginally significant positive effect—a pattern suggestive of hierarchy—and sociometric popularity had a significant positive effect. Residents who were perceived as powerful by more people had a greater likelihood of being named as powerful. This effect is symbolic of stability in social position over time (e.g., status maintenance).

We now evaluate the cross-network selection effects introduced in Models 2–6 (see Table 3). Model 2 tests the main cross-network effects of entrainment, which estimates the

Table 3 Cross-network estimates and standard errors from the stochastic actor-oriented Model

	Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE
"Get Along With" Network (i.e., Friendship Nominations)										
Power → Friendship (entrainment)	1.09	0.48*	1.20	0.51*	1.17	0.61 +	1.28	0.50*	1.15	0.61 +
Reciprocity with Power	–	–	1.26	0.68 +	1.21	0.65 +	–	–	1.48	0.77 +
Popularity—indegree Power alter [a]	–	–	–	–	0.06	0.27	–	–	0.38	0.39
XWX closure	–	–	–	–	–	–	− 0.5	0.24*	− 0.77	0.45 +
Power and Influence Network (i.e., Power Attributions)										
Friendship → Power (entrainment)	2.39	0.41***	2.06	0.49***	1.72	0.48***	2.02	0.43***	1.77	0.46***
Reciprocity with Friendship	–	–	1.48	0.60*	1.84	0.72*	1.46	0.66*	1.81	0.75*
Popularity—indegree Friendship alter [a]	–	–	–	–	1.61	0.91 +	–	–	1.45	0.79 +
OMC [b]	0.15		0.18		0.15		0.17		0.13	

Iterations at phase 3 = 10,000

SE standard error, *OMC* overall maximum convergence

[a] The transformation $\Phi(x) = \sqrt{x}$ is used for transforming the degrees in the role of independent variables

[b] Overall maximum convergence: For optimal convergence, a threshold of ≤ 0.25 is suggested for the overall maximum convergence ratio, and a threshold of 0.1 for the absolute value of the t statistics for deviations from targets

extent to which a tie in one network is associated with creating or maintaining a tie in the other network. There are significant positive effects in both directions, though magnitudes differ greatly. For example, residents were 2.97 ($e^{1.09}$) times more likely to befriend residents they considered powerful versus those not perceived as powerful, and 10.91 ($e^{2.39}$) times more likely to attribute power to residents whom they considered a friend versus non-friends. Thus, all else being equal, the presence of a friendship tie is a stronger predictor of perceiving someone as powerful than perceiving someone as powerful is predictive of friendship.

Introducing the entrainment effect reveals an interesting pattern of changes in other estimated effects. Effects in the friendship network are largely unchanged compared to Model 1. However, in the power network, the inclusion of friendship as a predictor reduced the effects of homophily on race (from $b = 0.61$ [$p < 0.01$] to $b = 0.25$ [n.s.]) and offense severity (from 1.73 [$p < 0.05$] to 1.40 [n.s.]; see Appendix E). The diminishing effect of race homophily is notable as this is one of the most persistent features of human network structure (McPherson et al. 2001).

Models 3–5 test additional cross-network effects while retaining entrainment as a main effect. Model 3 introduces cross-network reciprocity. An $i \rightarrow j$ friendship was 3.52 ($e^{1.26}$) times more likely if j perceived i to be powerful (i.e., $i \leftarrow j$ is present in the power network), though this effect is marginally significant. In the opposite direction, we see that an $i \rightarrow j$ tie in the power network was 4.39 ($e^{1.48}$) times more likely if j named i as a friend. We observe that reciprocity between power and friendship is driven by selection in both directions.

Model 4 introduces cross-network popularity effects. This effect is not statistically significant in the friendship network but is marginally significant in the power network. However, its positive valence suggests that, all else being equal, residents receiving more incoming friendship nominations from peers were more likely to be perceived as powerful by others (i.e., those who had not named them as friends).

We next considered the effect of cross-network transitivity (i.e., closure). Score tests of the transitivity effects in Fig. 1 for each network resulted in only one significant effect.[12] Thus, we added the XWX-closure effect to the friendship network. Model 5 reveals this effect to be statistically significant; however, its valence is negative. This suggests a tendency against befriending others who are connected to one's friends in the power network (either whomever one's friend perceives as powerful or whoever perceives one's friend as powerful). This effect is estimated net of other network mechanisms, including entrainment and transitivity in the friendship network. Thus, the XWX-closure effect represents when the $j \rightarrow k$ power attribution exists and leads i to friendships with j and k, but only absent a $j \rightarrow k$ friendship and friendships from i to the others. In combination, this suggests that there is no additional tendency for closure that exceeds the effects of closure within friendships and the direct effect of friendships on power attributions. We do not find evidence of other forms of cross-network triadic closure in friendship or perceived power networks.

Lastly, model 6 is the full model containing the cross-network effects from earlier models. Compared to the previous models, estimates slightly shift in strength but remain substantively unchanged. Thus, the cross-network effects identified earlier persist net of one another. We use these estimates from model 6 in our next step to calculate the relative importance (RI) of effects.

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[12] Score tests are chi-square distributed with one degree of freedom. For the friendship network, these were: *to* ($\chi^2 = 1.38$, $p = .24$), *closure* ($\chi^2 = .44$, $p = .51$), *cl.XWX* ($\chi^2 = 4.18$, $p = .04$). For the perceived power network, these were: *to* ($\chi^2 = .01$, $p = .94$), *closure* ($\chi^2 = 1.44$, $p = .23$), *cl.XWX* ($\chi^2 = .92$, $p = .34$).

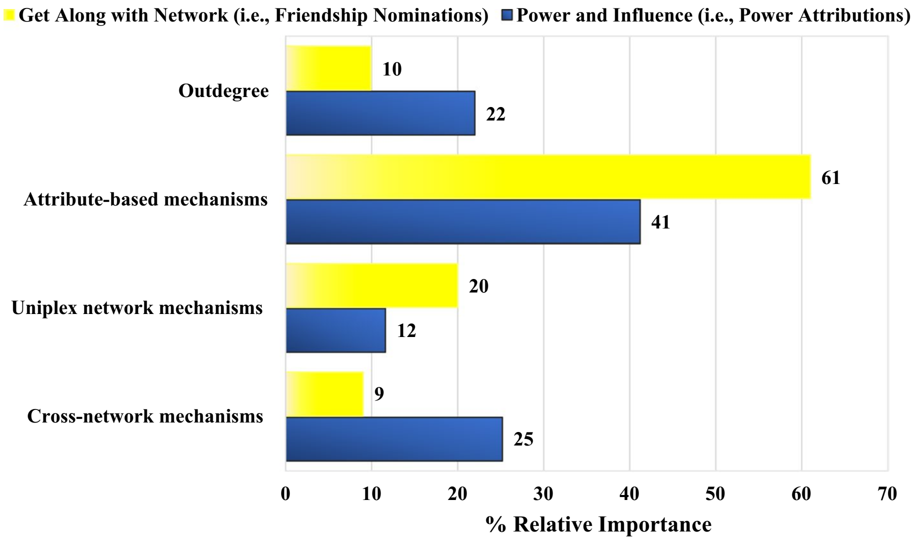


Fig. 4 Expected Relative Importance of Effects in the "Get Along With" (i.e., Friendship Nominations) Network and Power and Influence (i.e., Power Attributions) Network from Model 6

Relative Importance of Selection Mechanisms

To help contextualize the importance of effects, Fig. 4 presents relative importance (RI) scores aggregated within each class of selection mechanism: attribute-based, uniplex network, cross-network, and the outdegree effect (which carries little meaning but is included for completeness). In addition, our comparison considers the importance of effect class within each network and between the friendship and power networks (Appendix F provides relative importance of all effects separately for all models).

Results for RI reveal a contrast between the mechanisms responsible for change in friendship versus power attributions. Both networks were most strongly shaped by attribute-based mechanisms, which accounted for 61% of friendship network change, but only 41% of the change in power attributions. This was primarily attributable to homophily and popularity, which carried relatively equal shares in each network (28–29% each in the friendship network; 15–18% each in the power network). Turning to network mechanisms, we find that the friendship network was driven more strongly by uniplex effects (20.3%) than by cross-network effects (9.4%). This pattern is reversed in the power network, where RI was greater for cross-network mechanisms (24.6%) than uniplex network mechanisms (12.1%). These estimates suggest that changes in both networks were more strongly driven by the friendship network. That is, when predicting friendships, the uniplex effects carried more weight, whereas cross-network effects carried more weight in predicting the power network. By contrast, mechanisms based on the power network explained less change in either network. Thus, in sum, the friendship network was more consequential in shaping the evolving social structure than were individuals' perceptions of who was powerful.

Discussion

The prison social system is a web of multifaceted relations balanced amid convenience and caution (Crewe 2009). Changes in the prison population have transfigured prison society, somewhat diminishing the role of correctional staff in maintaining social order and managing conflicts (Crewe 2011; Hunt et al. 1993; Simon 2000; Wacquant 2001). These shifts contribute to a prison society whereby residents are given various forms of "power" and expected to organize, manage, and govern each other's behaviors (Crewe 2011; Hunt et al. 1993; Skarbek 2011; Trammell 2009). Coinciding with this need for residents to self-organize, however, is a high turnover rate in the prison population (Simon 2000; Vieraitis et al. 2007). Greater numbers of residents entering and leaving prison have made it increasingly difficult to maintain order, with friendships, loyalties, and alliances continuously tested (Hunt et al. 1993; Wacquant, 2001).

Despite such challenges, most relationships in prison do not culminate in manipulation, violence, or aggressive behaviors (Kerley and Copes 2009; Kreager et al. 2017, 2021). Instead, residents develop relationships that provide affective and instrumental support, which accumulate into a social structure characterized by friendship and power (Martin 2009; Robins et al. 2005). Over the last decade, scholars have discussed how friendship and power might be related in schools, formal organizations, and the workplace (Sauder et al. 2012), and some studies have even examined their temporal linkage (Labun et al. 2016; Torlò and Lomi 2017), but none that we know of have considered their co-evolution in a prison setting. We use a social network approach to understand how incarcerated men establish and maintain relationships with one another, evaluating the effects that give rise to friendship and power in prison and how much power is a function of friendship and vice versa.

Our first key finding is that different processes are responsible for friendship selection and power attributions. Our results for friendship are consistent with studies finding affective relations are characterized by reciprocity and transitivity (Rivera et al. 2010). However, the importance of these effects paled in comparison to attribute-based mechanisms, namely homophily and popularity. By contrast, power attributions were as strongly driven by network-based processes (i.e., uniplex and cross-network) and attribute-based mechanisms. This finding aligns with Labun et al. (2016), who found that homophily promoted friendships among workplace colleagues, with limited effects on power attributions. We observed homophilous power attributions based on race, religion, and offense severity in our base model; however, once we introduced cross-network selection to the model, the effects of homophily were attenuated. This pattern is consistent with mediation and implies that homophily affected power attributions indirectly through its direct effect on shaping the friendship network. It also suggests that while homophily may initially generate channels for residents to build rapport and potentially share information (also see Burt 2001), endogenous network processes build on these relations to fortify power structures.

Our second key finding derives from jointly examining the evolution of friendship and power attributions to estimate how strongly these two facets of social structure are associated. Our results point to the operation of several cross-network mechanisms: reciprocity, entrainment, and popularity. For most of these mechanisms, the effects of friendship on power were greater than the effect of power on friendship. Thus, our SAOM estimates point to friendship being a stronger driver of power attributions than vice versa. The relative importance results support this inference, with cross-network selection based on the friendship network accounting for a quarter of power attributions. In contrast, selection based on power attributions accounted for less than 10% of friend selection decisions. These findings diverge from Labun et al. (2016), who found stronger effects of power on friendship than vice versa. While there are many differences between our setting and their study of female employees in a Dutch school for special needs children, it is clear from both studies that power and friendship are intertwined. Namely, our results suggest that friendship is a "primary" structure, acting as a building block for group processes that allow influence to operate and power hierarchies to emerge in prison.

Third, our results help untangle the evolving nature of social structure within a prison. By conceptualizing social structure as a multidimensional, fluid entity, we identify the unique role that power and friendship play in recreating the prison social system. Indeed, the combination of homophilous selection and transitivity can result in subgroups within the unit. Interactions within groups allow for recurring acts of deference and control that can lead to the emergence of localized power and factions organized around background characteristics. This is evident in our base model, which found that race and religion homophily predicted power attributions. However, these effects weakened in later models that controlled for cross-network effects of friendship. This pattern suggests that similarities in race and religion helped residents decide whom to trust and who deserves their deference (Young and Haynie 2022). This could be because evaluations of trustworthiness are informed by culturally induced values, commonalities, and cooperation; therefore, deference arose within racially and religiously homogenous groups. Associations based on shared ethnic or racial background are common among organized criminals (Smith and Papachristos 2016; von Lampe and Johansen 2004), gang members (Grund and Densley 2012), and co-offenders (Carrington 2015; Charette and Papachristos 2017). Thus, like other high-risk interactions, in-prison friendships compound to create a network of collaborative relations where individuals support in-group members (e.g., via protection and reputational gains) while vying for power with outgroup members (Chase 1990; Gould 2002; Papachristos 2009).

Our study not only sheds light on questions of structure in prison society but also contributes to a broader discussion on network interventions (Valente 2012), which may be useful for prison administrators and staff. Namely, our study offers insight into how (and whether) incarcerated men establish and maintain relations, thus, providing direction on leveraging networks to promote positive institutional adjustments and maintain order within the prison environment. By recognizing that power is a localized phenomenon, with different residents attributing power to different people, prison administrators and correctional staff may be better equipped to maintain social order by focusing on powerful leaders within pockets of the hierarchy. In other words, by "mixing in with residents," staff may be able to sustain positive relations and their legitimacy with residents, incentivizing a select few to act as "opinion leaders" within and between their respective peer groups (Bottoms and Tankebe 2012; Valente 2012). This form of "soft power," which encourages residents to self-regulate and govern behaviors (Crewe 2011; Skarbek 2011) while allowing opportunities for personal development, may mitigate conflict, suspicion, and demystify some of the "unknowns" inherent in the prison environment (Kreager et al. 2017).

Relatedly, prison administrators also face challenges maintaining order with a revolving population. Understanding the origins of prison hierarchy can offer insight into what to expect as residents come or go. For example, when a respected leader leaves, who is likely to fill their place? Our results suggest that the existing power structure plays some role, but just as importantly, the structure of friendship relations matters. While staff cannot manipulate friendship, they can intervene to manipulate the precursors to friendship (e.g., cell assignments; see Schaefer and Kreager 2020), thereby offering some capacity to shape the informal structure that emerges within a unit.

From a policy perspective, it is important to consider long-term outcomes as almost all individuals sentenced to prison will be released at some point (Hughes et al. 2001). Focusing on this transition, a host of studies have highlighted the importance of in-prison experiences and behaviors for post-release outcomes (Caputo-Levine 2013; Cochran et al. 2014; Harding et al. 2017; Martin 2018; Visher and Travis 2003). In line with social learning perspectives, for example, repeated exposure to criminal peer groups is likely to shape individuals' offending trajectories (Akers 2017). This is no different in prison, where close contact with criminally sanctioned peers may increase opportunities to resume criminal behaviors or retain criminal ties. Thus, we might expect greater exposure to antisocial peers or negative experiences on the inside to increase the chance of recidivism (Huebner et al. 2007; Visher and Travis, 2003). However, this outcome is not a given. Residents create prison social order. Depending upon whom a resident chooses to befriend and whose lead they decide to follow, there is the potential for social learning that fosters criminogenic behaviors, but also social learning that promotes prosocial behaviors and a positive sense of self and identity after incarceration (Caputo-Levine 2013; Stuart and Miller 2017). This latter outcome may be more likely within a "good behavior" unit, where prosocial values such as wisdom, mentorship, and intelligence are the basis of the informal power structure (Kreager et al. 2017). By contrast, units where residents accrue power through antisocial behaviors (e.g., coercion, intimidation, and violence) (for example, see Liebling and Arnold 2012), which align with criminogenic behaviors on the street, may make it more difficult for residents to develop and sustain prosocial relationships. Understanding how prison social order, and more specifically prison experiences, are associated with antisocial and recidivist behaviors can provide opportunities to expand risk prediction methods and improve rehabilitative and programmatic efforts (Bottoms 1999; Gendreau et al. 1997; McCorkle 1992; Trulson et al. 2011).

Limitations and Conclusion

In considering these findings, it is important to note a few limitations. First, we rely on a single male "good behavior" unit in Pennsylvania. Unlike those housed in the general population, residents must demonstrate "good time" before entering the unit and thus exhibit prosocial behaviors that align with the institution's goals. While many prisons have similar types of units where our inferences could hold, prison units vary in ways likely to affect how friendships and power are produced (Colwell 2007; Skarbek 2014). Had we focused on a unit where risk was greater and trust harder to establish (i.e., gang or maximum-security units) or interactions more limited (i.e., segregated housing units), the social dynamics of residents may have differed (see Crewe 2009; Liebling and Arnold 2012; Skarbek 2014; van Hoven and Sibley 2008). Likewise, differences in how men and women navigate relationships may lead to different dynamics in a women's prison (Kreager et al. 2021). Ultimately, if the basis for power and friendship differs across contexts, we expect their respective emergent structures to differ, with consequences for their co-evolution (McFarland et al. 2014).

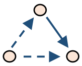
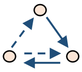
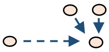
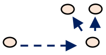
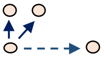
Second, we observe a good amount of resident turnover and missingness due to survey non-response. As such, it is reasonable to ask if this is a sufficient sample size to make inferences about change. Several features of our design make this less worrisome than may be the case: (1) Attribute data on all residents were provided by PADOC and had no missingness. Comparisons of the attributes of respondents and non-respondents reveal no systematic differences across waves. (2) Non-respondents could be named by respondents, meaning more than half of non-respondents incoming ties were measurable. Instead, missingness is limited to the outgoing ties of non-respondents. Non-respondents have fewer incoming power attributions and friendship nominations; therefore, their missing ties are more likely to be ties that are absent and not contributing to changes in other dyads. (3) The SAOM incorporates model-based imputation to impute ties for non-respondents at wave 2, which is preferable to alternative missing data treatments (Huisman and Steglich 2008). Outgoing ties of non-respondents at Wave 1 are assumed to be absent during model estimation, which is partially justifiable by their lower indegree. (4) Lastly, the 68 respondents at both waves could have nominated all 138 residents on the unit at both waves. That equates to 9316 dyads with valid tie data at both waves (68*137 [138–1 since residents could not nominate themselves]). In addition, the 69 residents who joined the unit at Wave 2 had to create new relationships or rekindle latent relationships. For those residents, it is not unreasonable to assume that they had few to no ties to unit residents at Wave 1. As such, ties from those 69 incoming residents to the 207 unit residents at Wave 2 can be classified as either forming or remaining absent (providing information on tie change for an additional 14,214 dyads: 69*206). Given that our models predict tie change at the dyadic level, our sample of 23,530 dyads measurable for change offers more power than would otherwise appear to be the case based on the number of residents in the study.

A more important issue regarding turnover is how residents entering, leaving, or transferring into and out of the unit within a relatively short timespan may have affected tie formation motivations and the selection mechanisms employed (Schaefer and Kreager 2020). For example, newer residents may not have had the chance to build friendships and establish the patterns of deference necessary to make power attributions. Residents who expect to leave the unit soon may have less motivation to invest in relationships than residents with longer anticipated tenures. While we show that movement to and from the unit is associated with an individual’s network position within the unit, an avenue for future studies is to empirically examine why select residents (i.e., non-continuous) tend to be less integrated and how network position is associated with their attributes, behavioral traits, and motives.

Finally, our interest was in understanding the systematic underpinnings of informal social structure. Our research questions precluded the assessment of causality through an experimental design as one cannot reasonably manipulate friendship and attributions of power within a prison. Indeed, experiments are less helpful for measuring the operation of systems in the natural world, including evolving social networks, where interdependencies between relations create endogenous feedback effects (Robins 2015). Such systems are better represented by dynamic models, which can be evaluated with computational experiments but must also be tested against empirical observations. Thus, while we cannot establish causality by virtue of design, we can offer insight into the temporal order of relationship changes. Specifically, SOAMs provide insight on time order sequence, linking power attributions with friendships for those where the state of one type of relation changed across periods of observations (Snijders and Pickup 2017).

Few have taken a dynamic network approach to unravel the multiple, complex relational processes at work in prison. By delving into systematic relational patterns, we could identify the foundational role of friendship relations in shaping power structures. Echoing calls by Akers (1977) that “studies of single prisons cannot adequately measure systematic variation in the prison environment itself” (p. 378), our approach should be extended to other prisons, especially those with different formal and informal governance mechanisms (Skarbek 2020). We argue that when variations in organizational and institutional culture exist, social networks are key to understanding the “black box” of prison society, offering a promising avenue for future research related to prison policies and institutional needs and adjustments (Kreager et al. 2016a, b; Whichard et al. 2022).

Appendix A: Attribute-based and Uniplex Network Effects used in the “Get Along With” (i.e., Friendship Nominations) Network and Power and Influence (i.e., Power Attributions) Network

Effect name	Short name	Diagram	Equation
Attribute—based effects			
ego	egoX		$v_i x_{i+}$
alter	altX		$\Sigma_j x_{ij} v_j$
same	sameX		$\Sigma_j x_{ij} I(vi = v_j)$
similarity	simX		$\Sigma_j x_{ij}(\text{sim}^v_{ij} - \widehat{\text{sim}}^v)$
Uniplex network effects			
reciprocity	recip		$\Sigma_j x_{ij} x_{ji}$
transitive triplets	transTrip		$\Sigma_{j,h} x_{ij} x_{ih} x_{hj}$
transitive reciprocated triplets	transRecTrip		$\Sigma_{j,h} x_{ij} x_{ji} x_{ih} x_{hj}$
popularity—indegree	inPop		$\Sigma_j x_{ij} x_{+j} = \Sigma_j x_{ij} \Sigma_h x_{hj} = \Sigma_j x_{ij}(\Sigma_{h\neq j} x_{hj} + 1)$
popularity—outdegree	outPop		$\Sigma_j x_{ij} x_{j+} = \Sigma_j x_{ij} \Sigma_h x_{jh}$
outdegree—activity (sqrt)	outActSqrt		$x_{i+}^{1.5} = x_{i+}\sqrt{x_{i+}}$

Dashed lines represent the tie being considered in a given selection decision, whereas solid lines represent existing ties in the same network. Our analysis assumes network change follows a Markov process in which only one tie can change at any time. Hence, for the transitivity effects, either dashed line would create transitivity, assuming the other dashed line is present.

Similarity effects (simX) are used for continuous attributes, it is the sum of centered similarity scores between *i* to all others, *j,* to whom *i* is tied to, whereas same effects (sameX) are used for categorical attributes, it considers the number of ties of *i* to all others, *j,* who have the same value on the attribute.

Patterned nodes indicate that a node’s attribute is being considered during selection.

An extensive description of these effects and their corresponding functions are available in the Manual for RSiena by Ripley et al. (2019).

Appendix B: Goodness of Fit Test

See Fig. 5.

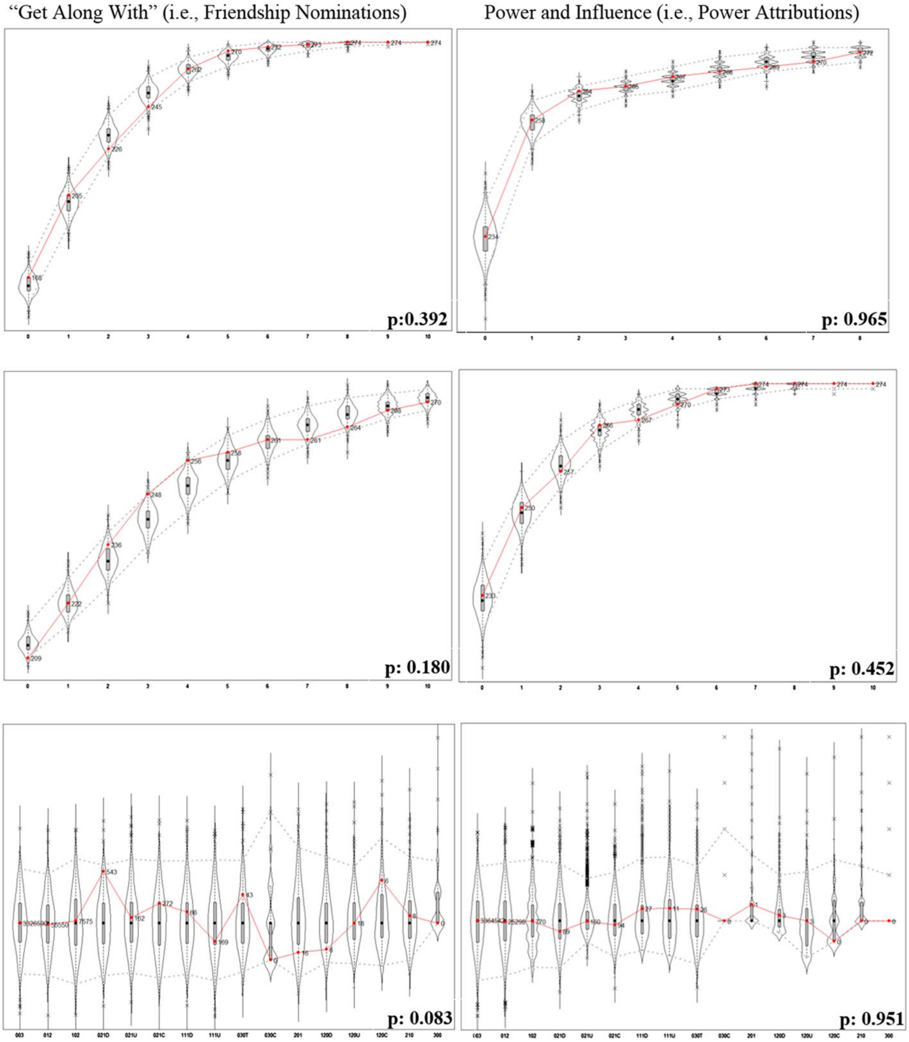


Fig. 5 “Get Along With” (i.e., Friendship Nominations) Network (left) and Power and Influence (i.e., Power Attributions) Network (right)—Top: Indegree Distribution; Center: Out Degree Distribution; Bottom: Triad Census; p = p-value

Appendix C: Indegree Centrality of Continuing Residents and Noncontinuing Residents

	Unit—Wave 1 (n = 205)					Unit—Wave 2 (n = 207)				
	Continuous (n = 138)		Noncontinuous (n = 67)		Strength of association	Continuous (n = 138)		Noncontinuous (n = 69)		Strength of association
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
"Get Along With" Network (i.e., Friendship Nominations)	3.90	2.92	2.36	2.34	− 3.77***	2.70	2.15	1.46	1.62	− 4.23***
Power and Influence Network (i.e., Power Attributions)	0.91	2.52	0.37	1.51	− 1.62	0.99	2.24	0.29	0.75	− 2.53*

Continuous indicates residents that were on the unit during wave 1 and wave 2 of the study. Noncontinuous indicates residents that were on the unit in wave 1 but not on the unit in wave 2 (left the unit after wave 1), and residents that were on the unit in wave 2 but not on the unit in wave 1 (joined the unit in wave 2)

Statistical differences between continuing residents and noncontinuing residents were determined using independent sample t-tests

Strength of association determined by value of t

SD standard deviation

*** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.10

Appendix D: Attributes of Respondents and Non-respondents/ Ineligible Residents

	Unit—Wave 1 (n = 205)				Strength of Association	Unit—Wave 2 (n = 207)				Strength of association
	Respondents (n = 133)		Non-respondents/ Ineligible (n = 72)			Respondents (n = 114)		Non-respondents/ Ineligible (n = 93)		
	% or mean	SD	% or mean	SD		% or mean	SD	% or mean	SD	
Age	38.91	11.35	40.51	10.74	0.98	37.37	11.17	41.94	10.84	2.94**
Years in prison	8.45	8.19	7.20	6.11	− 1.14	7.33	8.57	7.51	6.38	0.17

	Unit—Wave 1 (n = 205)				Strength of Association	Unit—Wave 2 (n = 207)				Strength of association
	Respondents (n = 133)		Non-respondents/ Ineligible (n = 72)			Respondents (n = 114)		Non-respondents/ Ineligible (n = 93)		
	% or mean	SD	% or mean	SD		% or mean	SD	% or mean	SD	
Years on unit	1.52	2.49	1.21	1.65	– 0.94	1.41	2.48	1.43	1.99	0.07
Offense gravity score	9.98	3.47	9.99	3.19	0.00	9.68	3.42	9.85	3.20	0.35
Gang or STG	0.08	0.28	0.01	0.12	– 2.01*	0.08	0.27	0.02	0.15	1.80+
Program participation	2.00	1.57	1.51	1.20	– 2.29*	0.50	0.72	0.41	0.73	-0.96
Race/Ethnicity					0.17 +					0.04
White/Other	21.46		17.56			22.55		16.67		
Black	33.66		13.17			25.98		22.55		
Hispanic	9.76		4.39			6.86		5.39		
Religion					0.15					0.08
Muslim	15.61		5.85			13.50		9.00		
Catholic	12.68		5.85			8.50		8.00		
Protestant	10.73		9.76			13.50		11.50		
Other religion	16.59		7.80			12.50		12.00		
No religion	9.27		5.85			7.00		4.50		
Indegree										
"Get Along With" Network (i.e., Friendship Nominations)	3.93	3.07	2.40	1.99	– 3.81***	2.71	2.31	1.77	1.59	– 3.32**
Power and Influence Network (i.e., Power Attributions)	1.00	2.73	0.25	0.60	– 2.30*	0.96	2.37	0.51	1.07	– 1.73+

Statistical differences between respondents and nonrespondents were determined using independent sample t-tests and chi-square tests

Strength of association determined by Cramer's V, or value of t

SD, standard deviation, *STG* security threat group

***p < 0.001; **p < 0.01; *p < 0.05; + p < 0.10

Appendix E: Estimates and Standard Errors from the Stochastic Actor-Oriented Model

(A)“Get Along With” Network (i.e., Friendship Nominations)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Rate	13.40	1.16***	13.92	1.28***	13.90	1.27***	14.01	1.26***	13.71	1.29***	13.58	1.22***
Outdegree (density)	− 3.61	0.57***	− 3.40	0.45***	− 3.37	0.54***	− 3.24	0.66***	− 3.47	0.56***	− 2.98	0.75***
Attribute-based effects												
Age (log) alter	− 0.83	0.25**	− 0.91	0.26***	− 0.92	0.28**	− 1.01	0.38**	− 0.82	0.26**	− 1.07	0.41*
Age (log) ego	− 0.23	0.24	− 0.22	0.23	− 0.27	0.25	− 0.28	0.24	− 0.19	0.23	− 0.24	0.25
Age (log) similarity	0.81	0.31**	0.80	0.30**	0.78	0.31*	0.77	0.31*	0.80	0.31**	0.76	0.33*
Years on unit (log) alter	0.40	0.10***	0.38	0.11***	0.38	0.12***	0.42	0.15**	0.37	0.11***	0.42	0.18*
Years on unit (log) ego	− 0.09	0.08	− 0.09	0.08	− 0.11	0.09	− 0.11	0.09	− 0.09	0.08	− 0.11	0.10
Years on unit (log) similarity	0.87	0.57	0.74	0.58	0.78	0.64	0.76	0.62	0.96	0.59	1.00	0.75
Offense severity alter	− 0.05	0.02*	− 0.06	0.02*	− 0.05	0.03*	− 0.06	0.03 +	-− 0.05	0.02*	− 0.07	0.04 +
Offense severity ego	0.06	0.02*	0.07	0.02**	0.06	0.03*	0.06	0.03*	0.06	0.02**	0.05	0.03 +
Offense severity similarity	0.34	0.33	0.34	0.35	0.34	0.35	0.35	0.37	0.41	0.36	0.50	0.39
Gang or STG alter	1.05	0.57 +	0.83	0.44 +	0.79	0.52	0.76	0.52	0.95	0.55 +	0.86	0.62
Gang or STG ego	− 1.23	0.98	− 1.12	0.68 +	− 1.37	0.81 +	− 1.33	0.72 +	− 1.17	0.90	− 1.48	0.96
Gang or STG same	0.79	0.54	0.67	0.40 +	0.66	0.49	0.66	0.42	0.66	0.49	0.67	0.56
Race same	0.49	0.10***	0.48	0.11***	0.49	0.11***	0.49	0.11***	0.46	0.11***	0.47	0.11***
Religion same	0.22	0.11 +	0.20	0.11 +	0.19	0.11	0.18	0.12	0.21	0.12 +	0.19	0.12
City same	0.20	0.15	0.16	0.16	0.12	0.16	0.11	0.17	0.20	0.16	0.16	0.16
Uniplex network effects												
Reciprocity	2.15	0.30***	2.13	0.27***	1.96	0.32***	1.97	0.35***	1.97	0.33***	1.83	0.37***
Transitive triplets	0.73	0.11***	0.73	0.12***	0.77	0.12***	0.77	0.12***	0.87	0.13***	1.05	0.22***
Transitive reciprocated triplets	− 1.04	0.35**	− 1.09	0.35**	− 1.30	0.41**	− 1.27	0.41**	− 0.89	0.36*	− 1.08	0.41**

(A)“Get Along With” Network (i.e., Friendship Nominations)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Popularity—indegree	− 0.05	0.04	-− 0.07	0.05	− 0.06	0.05	− 0.09	0.10	− 0.06	0.05	− 0.16	0.14
Popularity—outdegree	− 0.04	0.04	− 0.05	0.04	− 0.06	0.04	− 0.07	0.05	− 0.04	0.04	− 0.07	0.05
Cross-network effects												
Power—> Friendship	–	–	1.09	0.48*	1.20	0.51*	1.17	0.61 +	1.28	0.50*	1.15	0.61 +
Reciprocity with Power	–	–	–	–	1.26	0.68 +	1.21	0.65 +	–	–	1.48	0.77 +
Popularity—indegree Power alter[a]	–	–	–	–	–	–	0.06	0.27	–	–	0.38	0.39
XWX closure	–	–	–	–	–	–	–	–	− 0.50	0.24*	− 0.77	0.45 +

(B) Power and Influence Network (i.e., Power Attributions)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Rate	5.68	0.98***	6.12	1.12***	6.40	1.54***	6.20	1.22***	6.14	1.15***	6.23	1.36***
Outdegree (density)	− 5.92	0.78***	− 6.11	0.76***	− 6.36	0.96***	− 6.78	1.01***	− 6.30	0.87***	− 6.71	0.90***
Attribute-based effects												
Age (log) alter	− 0.09	0.41	0.03	0.45	− 0.07	0.48	0.88	0.84	− 0.13	0.46	0.69	0.68
Age (log) ego	0.70	0.52	0.40	0.54	0.57	0.56	0.73	0.60	0.58	0.55	0.69	0.60
Age (log) similarity	0.48	0.59	0.44	0.66	0.48	0.67	0.34	0.79	0.43	0.69	0.32	0.74
Years on unit (log) alter	0.28	0.15+	0.18	0.16	0.22	0.18	-0.29	0.29	0.20	0.17	-0.25	0.27
Years on unit (log) ego	0.24	0.17	0.16	0.18	0.12	0.19	0.10	0.20	0.11	0.19	0.09	0.19

(B) Power and Influence Network (i.e., Power Attributions)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Years on unit (log) similarity	1.75	1.07	0.99	1.15	0.60	1.29	0.56	1.27	0.60	1.38	0.47	1.37
Offense severity alter	0.09	0.04*	0.10	0.04*	0.09	0.05+	0.14	0.07*	0.09	0.05+	0.14	0.06*
Offense severity ego	-0.11	0.05*	-0.10	0.05+	-0.10	0.06+	-0.11	0.06*	-0.11	0.06+	-0.10	0.05+
Offense severity similarity	1.73	0.74*	1.40	0.78+	1.33	0.79+	1.54	0.84+	1.35	0.79+	1.38	0.86
Gang or STG alter	0.61	0.40	0.49	0.41	0.64	0.44	0.44	0.51	0.59	0.46	0.42	0.52
Gang or STG ego	0.26	0.42	0.48	0.45	0.52	0.47	0.45	0.49	0.47	0.46	0.42	0.50
Gang or STG same	0.65	0.40	0.55	0.43	0.52	0.44	0.54	0.46	0.49	0.45	0.50	0.46
Race same	0.61	0.20**	0.25	0.23	0.15	0.24	0.12	0.26	0.16	0.25	0.14	0.26
Religion same	0.48	0.20*	0.47	0.22*	0.46	0.25+	0.41	0.24+	0.45	0.24+	0.40	0.24+
City same	0.27	0.26	0.12	0.30	0.17	0.31	0.07	0.33	0.17	0.31	0.03	0.33
Uniplex network effects												
Reciprocity	0.29	0.65	− 0.52	0.68	− 1.63	0.80*	− 1.64	0.87+	− 1.47	0.79+	− 1.69	0.88+
Transitive triplets	0.50	0.27+	0.32	0.27	0.27	0.27	0.17	0.26	0.33	0.26	0.27	0.25
Popularity—indegree	0.09	0.03**	0.10	0.03**	0.10	0.04*	0.02	0.06	0.10	0.04**	0.02	0.06
Popularity—outdegree	0.05	0.08	0.09	0.08	0.10	0.09	0.05	0.11	0.10	0.08	0.07	0.10

(B) Power and Influence Network (i.e., Power Attributions)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE
Outdegree—activity (sqrt)[a]	0.34	0.20+	0.44	0.20*	0.54	0.22*	0.62	0.23**	0.55	0.22*	0.60	0.20**
Cross-network effects												
Friendship -> Power	–	–	2.39	0.41***	2.06	0.49***	1.72	0.48***	2.02	0.43***	1.77	0.46***
Reciprocity with Friendship	–	–	–	–	1.48	0.60*	1.84	0.72*	1.46	0.66*	1.81	0.75*
Popularity—indegree Friendship alter[b]	–	–	–	–	–	–	1.61	0.91+	–	–	1.45	0.79+
OMC[c]	0.16		0.15		0.18		0.15		0.17		0.13	

To decrease correlation with other effects all covariates are centered prior to estimation

[a] The square-root transformation of the *outdegree activity* effect in the power network improved overall model fit

[b] The transformation $\Phi(x) = \sqrt{x}$ is used for transforming the degrees in the role of independent variables

[c] Overall maximum convergence: For optimal convergence, a threshold of ≤ 0.25 is suggested for the overall maximum convergence ratio, and a threshold of 0.1 for the absolute value of the t statistics for deviations from targets. Iterations at phase $3 = 10{,}000$

SE standard error, *STG* security threat group, Sim, Similarity, sqrt, square root function; log, logged transformation; OMC, Overall Maximum Convergence

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}\ p < 0.05$; $+\,p < 0.10$

Appendix F: Expected Relative Importance of Effects Model 1 to Model 6

	"Get Along With" Network (i.e., Friendship Nominations)											
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Outdegree	0.12	0.13	0.11	0.13	0.11	0.13	0.10	0.12	0.12	0.14	0.09	0.10
Age (log) alter	0.08	0.07	0.09	0.08	0.09	0.09	0.10	0.09	0.08	0.08	0.08	0.08
Years on unit (log) alter	0.14	0.13	0.14	0.13	0.14	0.13	0.14	0.13	0.13	0.12	0.12	0.11
Offense severity alter	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.05	0.06	0.06
Gang or STG alter	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03
Age (log) ego	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01
Years on unit (log) ego	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Offense severity ego	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01
Gang or STG ego	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02
Age (log) similarity	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.04	0.04
Years on unit (log) similarity	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03
Offense severity similarity	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Gang or STG same	0.11	0.12	0.09	0.10	0.09	0.10	0.09	0.10	0.10	0.10	0.08	0.09
Race same	0.11	0.10	0.11	0.10	0.11	0.10	0.10	0.09	0.10	0.09	0.08	0.08
Religion same	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.02
City same	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Reciprocity	0.04	0.05	0.04	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.02	0.03
Transitive triplets	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03
Transitive reciprocated triplets	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

	"Get Along With" Network (i.e., Friendship Nominations)											
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Popularity—indegree	0.04	0.04	0.05	0.05	0.05	0.05	0.07	0.06	0.05	0.05	0.10	0.09
Popularity—outdegree	0.05	0.04	0.05	0.04	0.06	0.05	0.06	0.06	0.04	0.03	0.05	0.05
Power—> Friendship	–	–	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Reciprocity with Power	–	–	–	–	0.01	0.01	0.01	0.01	–	–	0.01	0.01
Popularity—indegree Power alter	–	-	–	–	–	–	0.01	0.01	–	–	0.08	0.07
XWX closure	–	–	–	–	–	–	–	–	0.00	0.01	0.01	0.01

Power and Influence Network (i.e., Power Attributions)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Outdegree	0.19	0.21	0.24	0.27	0.26	0.29	0.18	0.22	0.26	0.28	0.20	0.24
Age (log) alter	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.04	0.01	0.01	0.03	0.03
Years on unit (log) alter	0.08	0.08	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.05
Offense severity alter	0.07	0.07	0.08	0.07	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.07
Gang or STG alter	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Age (log) ego	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Years on unit (log) ego	0.03	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01
Offense severity ego	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.03
Gang or STG ego	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Age (log) similarity	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01
Years on unit (log) similarity	0.06	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01
Offense severity similarity	0.07	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.04

Power and Influence Network (i.e., Power Attributions)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Gang or STG same	0.10	0.10	0.09	0.09	0.08	0.08	0.06	0.06	0.08	0.08	0.06	0.06
Race same	0.10	0.09	0.04	0.04	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01
Religion same	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.02	0.04	0.04	0.03	0.02
City same	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
Reciprocity	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Transitive triplets	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Popularity—indegree	0.05	0.05	0.05	0.06	0.04	0.05	0.01	0.01	0.05	0.05	0.01	0.01
Popularity—outdegree	0.01	0.02	0.02	0.03	0.02	0.04	0.01	0.01	0.02	0.04	0.01	0.02
Outdegree—activity (sqrt)	0.05	0.06	0.08	0.08	0.09	0.10	0.08	0.08	0.10	0.10	0.08	0.08
Friendship—> Power	–	–	0.06	0.04	0.05	0.03	0.04	0.02	0.05	0.03	0.04	0.02
Reciprocity with Friendship	–	–	–	–	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Popularity—indegree Friendship alter	–	–	–	–	–	–	0.20	0.19	–	–	0.19	0.18

STG, Security Threat Group; sqrt, square root function; log, logged transformation.

*** p < 0.001; **p < 0.01;* p < 0.05; + p < 0.10

Acknowledgements The contents of this article are those of the authors and do not necessarily reflect the official views of the respective agencies. We greatly appreciate the data collection efforts of the PINS team. We are also grateful to the residents for sharing their insights and the prison staff and PADOC for their support of this project. This manuscript benefited from helpful comments provided by the editor-in-chief and anonymous reviewers.

Funding This research was funded by a grant from the National Science Foundation (LSS-1457193).

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