Formation of raiding parties for intergroup violence is mediated by social network structure

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Intergroup violence is common among humans worldwide. To assess how within-group social dynamics contribute to risky, between-group conflict, we conducted a 3-y longitudinal study of the formation of raiding parties among the Nyangatom, a group of East African nomadic pastoralists currently engaged in small-scale warfare. We also mapped the social network structure of potential male raiders. Here, we show that the initiation of raids depends on the presence of specific leaders who tend to participate in many raids, to have more friends, and to occupy more central positions in the network. However, despite the different structural position of raid leaders, raid participants are recruited from the whole population, not just from the direct friends of leaders. An individual’s decision to participate in a raid is strongly associated with the individual’s social network position in relation to other participants. Moreover, non-leaders have a larger total impact on raid participation than leaders, despite leaders’ greater connectivity. Thus, we find that leaders matter more for raid initiation than participant mobilization. Social networks may play a role in supporting risky collective action, amplify the emergence of raiding parties, and hence facilitate intergroup violence in small-scale societies.

Significance

The social network structure of a small-scale society is crucial to formation of raiding parties involved in violent between-group raids. We mapped the social networks among Nyangatom men in a defined area of Ethiopia and ascertained membership in 39 intergroup raiding parties over 3 y. Although a small set of leaders initiated raids, they were not especially crucial for the composition of the raiding parties; instead, aspects of social network structure served to determine group composition and to amplify group size, once a raid was initiated. Intergroup violence, like other forms of collective action, depends on social structure and not just individual agency. This is relevant to spontaneous violent activities in settings as diverse as revolutions, gangs, and terrorist groups.


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To address how social networks influence the emergence of violence, we mapped the social ties in a nonstate society in which groups engaging in violent intergroup raiding formed organically, analyzing the role of social networks in instigating and sustaining intergroup conflict. Using observations derived from long-term ethnographic fieldwork, coupled with detailed mapping of the social network of raiding-aged men, we present data from a complete set of 39 discrete intergroup conflict events among the Nyangatom, a society of nomadic agro-pastoralists inhabiting a remote region along the border of South Sudan and Ethiopia largely outside the reach of state institutions (38, 39).

The Nyangatom

Many Nyangatom live in mobile cattle camps containing between 10 and 100 persons, and the population and number of these camps are not fixed (38). Depending on seasonal variation, camps may disband (with residents forming new camps) or they may aggregate and form larger villages. The Nyangatom also have semipermanent villages with dynamic membership, and movement between camps and villages is common. Livestock have a central place in the culture and diet of the Nyangatom and are necessary for many social exchanges, including marriage. To marry, a male is required to provide the family of the bride with bride wealth, often 30–60 cattle but sometimes as many as 100 cattle. Therefore, livestock are highly sought after, and violent conflict with other groups to obtain them is common (38–40). The Nyangatom also have a distinctive social organization involving sequential generation sets and age sets (38); most males engage in activities such as herding, socializing, and raiding with members of their age group, creating strong social bonds between members (38).

The primary type of intergroup conflict event for the Nyangatom is the raid (singular enoji rîmonô), in which a small group of men attempt to locate and seize livestock from other nearby ethnic groups, kill enemies they encounter when they can do so with minimal risk, and then escape unharmed. Casualties among members of raiding parties are unusual as they seek to minimize personal risk, but injuries and deaths of members of enemy groups are common, and fatalities among raiders are not unheard of. Successful raiders receive captured livestock (18, 39) and sometimes other social benefits, such as status, honorific names and scars, and public praise (9, 41). Raids generally begin with one or more leaders who attempt to locate other partisans, typically takes several days. Raiding parties can also emerge when large groups of young men are congregated, such as during a ceremony. Individuals are not compelled to join a raiding party, and many young men elect not to join; and there are no formal sanctions for cowardice, desertion, or failure to participate (39).

Results

We used extensive semistructured interviews to collect information regarding intergroup conflict events that occurred between the Nyangatom and their neighbors. We comprehensively identified all 91 men residing in the study area who were of the appropriate age for raid participation (~18–45 y) and established group composition for a complete set of all intergroup raids initiated during the study period (n = 39; Methods). We measured a variety of attributes of potential raiders, including height, weight, kin relationships, and measures of paternal wealth (Dataset S1, Table S1). We also performed a comprehensive, sociocentric network study of this population of Nyangatom males. To measure friendship ties within this group, we used a gift task modeled on prior work with the Hadza hunter-gatherers of Tanzania (33) in which Nyangatom were asked to identify other study participants to whom they would like to give an anonymous gift.

On average, there was one raid every 4.7 wk, and raids were generally nonoverlapping in time, with raiding forays typically lasting several days. Most of the population (78 of 91) participated in at least one raid (mean participation, 2.9 raids; SD, 3.3). On average, about 7 men (SD, 3.4) participated in each raid (Fig. 1L); roughly 80% of raids in our sample were successful, resulting in an average of four head of livestock (including cattle, goats, and donkeys) being captured by each raider of a successful raid.

Measured individual-level characteristics were tested for association with raid participation in bivariate models without controls— including the number of siblings, height, weight, and measures of paternal wealth (Dataset S1, Tables S2–S5). Although the number of siblings, weight, and paternal wealth were significant in bivariate models, none of these egocentric characteristics remains significant in a multivariate model (Dataset S1, Table S7). That is, we did not find evidence that these variables were independently relevant to whether a person went on a raid. However, a bootstrap analysis showed that the average weight of a leader is higher than that of a nonleader (P = 0.010), whereas neither the height (P = 0.468) nor the number of siblings (P = 0.364) is significantly different between leaders and nonleaders (SI Methods).

Fig. 1F shows a bipartite network of all 91 subjects and all 39 raids, with the five individuals identified as leaders on any raid shown in red. Leaders were clearly the most participatory, and all raids had at least one of these leaders. To complement the ethnographic data, we also used the raid participation data alone (Fig. 1B) to conduct a “minimal set analysis” to independently identify leaders (SI Methods). This analysis attempts to identify the smallest group of individuals at least one of whom participated in every raid. The procedure successfully identified all five individuals that were named as leaders on any raid by participants. These five individuals also participated in significantly more raids than expected due to chance (all P << 0.001) as determined by a procedure where we randomly reassigned the identities of those who participated in each raid while keeping the distribution of raid participation fixed (SI Methods). Intriguingly, these results show that leaders can be successfully identified from raid participation data alone without prior information on the roles of each participant. Because there was no raid that did not include at least one leader, these results also suggest that leadership has an important role in the formation of intergroup violence.

The social network of raiding-age Nyangatom men is shown in Fig. 2, with those who did not participate in any raids shown in green, those who participated in at least one raid in blue, and leaders shown in red. Node size corresponds to the number of raids named as leaders by participants.
in which a person participated (larger indicates more raids). The mean number of incoming friendship nominations (in-degree) was 3 (SD, 2.7), and the range was 0–13.

Although in-degree is associated with both wealth and number of siblings, the strongest predictor of the number of friendship nominations is leadership status. Leaders have more than twice as many friends (defined by receiving gifts) as nonleaders (5.2 vs. 2.4) and the difference is strongly significant (P = 0.01). Leaders also score significantly higher on a measure of network centrality, even when controlling for in-degree (P = 0.04) (SI Methods). This means that leaders not only have more friends but also that their friends tend to be more popular, meaning leaders also have more friends of friends as well.

We explored the ways the Nyangatom social network is similar to certain other social networks by measuring a comprehensive set of statistics (33). Although the cumulative degree distribution (Fig. 1C) does not appear to differ significantly from a random network (P = 0.76), a number of other important properties are shared with nonrandom social networks. Reciprocity (the probability that a participant B names participant A as a friend, given that participant A names participant B) is significantly higher in the Nyangatom network (reciprocity, 0.37) than in a random network (P < 0.001); that is, there are significantly more two-way friendship ties in the real network than a random network. In addition, at 0.17, transitivity (the probability that two of a participant’s friends are friends with one another) is also significantly higher in the Nyangatom network than a random network with the same number of vertices and edges (P < 0.001). Finally, there is also strong homophily (the tendency of people with similar characteristics to have social ties with one another) by age group (0.88, P < 0.001) (Fig. S1) and by degree (0.10, P = 0.04). This homophily by age partly reflects the fact that the primary social interactions for males in Nyangatom society occur between members of the same age group; and our assessment of social ties also shows stronger connections within age groups than between age groups, thus supporting the validity of the gift-giving task as a measure of social connections among the Nyangatom.

Social network structure is highly relevant to the composition of raiding groups, and membership in raiding groups does not arise by chance. Fig. 3A shows that individuals with more social connections (i.e., higher degree) tend to go on more raids, even when we exclude the five leaders from the analysis and more popular nodes (those with higher degree) tend to go on more raids (Fig. S2). Each additional social connection is associated with an increase of 0.45 raids (SE, 0.17; P = 0.01) in the expected number of raids in which a subject participates. In fact, regression models that include in-degree, height, weight, wealth, and number of siblings show that social relationship “capital” is more strongly associated with raid participation than physical or material capital (SI Methods). Although we expect that having more social connections leads to more invitations or pressure to participate in raiding parties, it is also possible that increased raiding contributes to a greater number of social connections. Although wealth is associated with participation, the association becomes insignificant when we exclude leaders from the model (SI Methods). Our measure of network in-degree is the only variable that survives various model specifications.

However, the emergence of violent collective behavior is more nuanced than leaders simply being linked by friendship ties to nonleader “followers.” We used regression analysis to evaluate the decision to join a raid, examining how this decision is associated with the total number of other people who join the raid, the number of one’s friends in particular who participate, and the number of other leaders who participate (SI Methods). In these models, we treated each individual’s decision to participate in each raid as the dependent variable, and we assessed how the presence of other potential raiders was associated with the probability that an individual would participate in a raid. To control for unobserved characteristics of individuals (e.g., their attitudes toward violence or risk, as well as other personality factors) and of raids (e.g., the distance to the raid target or the anticipated value of the raided items), we included in the model fixed effects for both individuals and raids. Although raid size was not significantly associated with decisions to join raids, leader and friend participation was. Specifically, subjects were 6.8% (SE, 2.4%) more likely to join raids if they were directly connected by friendship to a leader in that raid. If, on

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the other hand, they were friends of friends with the leader (social distance 2) or friends of friends of friends (social distance 3), they were no more likely to join (Fig. 3B). This suggests that leaders may be able to mobilize their direct friendship contacts to join raids. However, further analysis yields an important observation that, if so, leaders are no more able to mobilize their friends than is anyone else in the population. Each nonleader friend who participated in a raid increased the likelihood that a person joined by 19.2% (SE, 1.4%), which is significantly higher than the boost in probability associated with leader friends participating ($P < 10^{-5}$).

Although leaders appear to be less relevant than nonleaders for predicting any one decision to join a raid, recall that leaders are much better connected to the network. It is possible that leaders may have less effect per person, but a greater total effect because they are connected to more people. However, a test of this hypothesis fails. In a model where we regress total participation by a person’s friends on a person’s decision to join, their leadership status, and an interaction variable that indicates the effect of leadership on total mobilization, we find that significantly fewer people join when a leader joins than when a nonleader joins ($P = 0.008$) (SI Methods). In other words, the key motivating factor to join a raid once a raid is initiated is not leadership; it is friendship.

Social distance has an unusual relationship in the results for nonleader friends (Fig. 3B). After controlling for friend participation, each friend of a friend who participates in a raid actually decreases the likelihood a person will join by 1.6% (SE, 0.6%; $P = 0.006$). This suggests that people just outside of a person’s direct social network may actually slightly demotivate participation in raids; weak ties are apparently not useful for recruiting and may even be somewhat detrimental. This also suggests that the men indeed have different sorts of relationships with each other, even within a population of just 91 individuals. The significance of these associations survives models with various controls (SI Methods).

Finally, a model with sibling participation did not provide evidence for siblings being more or less likely than chance to raid with each other ($P = 0.23$) (SI Methods). Thus, it appears that kinship did not influence raiding-party composition, consistent with prior work with humans (37).

Discussion

A rich picture appears regarding the role of leadership and social network structure in the emergence of collective intergroup violence in this evolutionarily relevant population. Leaders appear to matter mechanistically, functioning as focal points or as nucleation sites for raids among the Nyangatom. Although they participate most often (the five leaders are the top five participants, by status, and an interaction variable that indicates the effect of prior work with humans (37). This is consistent with the notion that individual variation—either by reducing the costs of the raid to individuals or even dyads, and instead may at least partially, suggest two things with respect to the prospect of managing...
Methods

Data were collected as part of an ongoing ethnographic study of the Nyangatom in which one of the researchers (L.G.) intermittently resided in the study area in Ethiopia between 2009 and 2012. We used semi-structured interviews to collect information regarding intergroup conflict events that occurred between the Nyangatom and their neighbors, including the Turkana, Daasanach, and Suri. We identified 91 men residing in the study area who were of the appropriate age to participate in raids (~18–45 y). We conducted interviews with each of these individuals, collecting data on their conflict history including both successful and unsuccessful raids; raiding-party composition was validated through peer reports. The presence of a raider on a raiding party was determined by an individual’s participation in the raiding party for any portion of it; we did not measure desertion, and some individuals may have ceased their participation during the actual raid because they were afraid or for other reasons. Leadership was ascertained by cross-validated personal accounts elicited by questions about whether any person was a leader of the raid using two Nyangatom terms for leader (singular Ekanikon; singular Eketamunan).

We also performed a comprehensive, sociocentric network study of the entire population of raiding-age Nyangatom males (n = 91). To measure friendship ties within this group, we used a gift task modeled on prior work with the Hadza hunter-gatherers of Tanzania (33) in which the Nyangatom subjects were asked to identify other study participants to whom they would like to give a gift of candy. Giving a gift is an important measure of friendship ties within this group, we used a gift task modeled on prior work.

To explore associations between raid characteristics and raid participation, we evaluated linear regression models that estimated the association between an individual’s decision to join a particular raid and various raid characteristics. The basic model is as follows:

\[ E[Y_{ij}] = \theta_0 + \gamma_i + \beta x_{ij}, \]

where the dependent variable \( Y_{ij} \) is 1 if person j joins raid r, and 0 otherwise; \( x_{ij} \) is a vector of characteristics for participant i and raid r; and \( \theta_0 \) and \( \gamma_i \) are individual and raid fixed effects, respectively. We report results of the linear model for more intuitive interpretation. The results are consistent in both sign and magnitude compared with generalized linear models. See SI Methods for further description of methods.

Approval for this study was obtained from the Harvard University Committee on the Use of Human Subjects, the South Omo Zone, Southern Nations, Nationalities, and Peoples’ Region, Federal Democratic Republic of Ethiopia; and local elders. Informed consent was obtained from all participants.

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Supporting Information

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SI Methods

Study Population. The Nyangatom number between 20,000 and 30,000 and live along the Ethiopian and South Sudanese border in and adjacent to the Lower Omo Valley of Ethiopia. Research was conducted in a border area along the Nyangatom–Turkana frontier to the north of the Kibish River and west of the Kuraz Mountains.

The residence structure of the Nyangatom is dynamic. Many Nyangatom reside in mobile villages. These villages may exist for several weeks or longer before disbanding or relocating. Sometimes, members of multiple camps or villages may join together to form a larger village or larger villages may break up into smaller villages. A particular village composition usually results from considerations for providing suitable resources for livestock as well as to maximize security. There are also semipermanent villages in settled areas, but the population is highly dynamic. Individuals commonly move between these villages and the mobile villages. Young men are generally not attached to any one village for their primary residence, but instead are attached to the livestock owned by their father or other paternal relatives and change their residence based on the movements of these livestock.

The Nyangatom are organized into territorial sections (plural ngiicala). Membership provides culturally recognized rights to resources in a certain areas of Nyangatom territory. Thus, men living in a specific area generally share membership in common territorial sections. Although individuals may change their residence multiple times a year, they usually do so within a constrained area of Nyangatom territory and revisit the same areas seasonally.

Because of the complex residence dynamics of the Nyangatom in the study area, conducting an analysis of village residence was impractical. Rather, we identified individuals who resided at least seasonally in the study area and were the appropriate age to participate in raids. Men who are elders (singular ekasuko) do not participate in raids. Although we lack data on their ages, elders are estimated to be above 45 y of age. We also exclude young men below the ages of ∼18 because they usually do not participate in raids. We identified our sample (n = 91) by their membership in culturally specific age groups where men are deemed old enough to engage in activities such as cattle herding and raiding but not old enough to be elders.

These individuals are expected to be familiar with each other for several reasons. First, the dynamic residence structure ensures that individuals may have resided with each other in the same village. Second, when resources allow, multiple herds of livestock graze together in grazing areas. This usually occurs after the rainy season but can occur at other times as well. In this cases, men from a large area herd together providing collective defense. Finally, there are many ceremonial engagements in which men from throughout the area come together during which ceremonies are performed and animals are slaughtered and communally consumed. These ceremonial activities allow men from the study population to spend time together on a semiregular basis.

Male subjects had facial photographs taken for identification purposes. Each subject was assigned a unique identification number that was used to match the photograph to the subject. Photographs were compiled onto two photo sheets measuring 30 × 35 cm each, containing 42 and 49 photographs. Each photograph measured 3 × 5 cm. The photo sheets (supplemented by individual photographs) were used to allow participants to make visual identification of other study participants.

Study participants were compensated with local currency (approximately US$0.25 to US$1.00), tea, or sugar for their participation in study elements. A translator was used for the semistructured interviews, and interviews would proceed by the researcher presenting the question to the translator who would ask the question and then translate the answer back to the researcher. The researcher (L.G.) also directly asked interview questions or follow-up questions if the subject’s answers were not clear.

Because the field researcher was based at the field site for an extended period, data collection occurred throughout the duration of the study and multiple interviews were conducted with study participants. Interviews were frequently conducted with the subject alone. However, due to the open nature of the society, subjects would sometimes be joined by their friends or relatives. Subject comprehension and accuracy was validated in the field by using consistency checks within and between interviews. These involved asking participants to repeat their answers to questions to test for consistency with their previous answers.

Conflict Landscape. The threat of conflict is a daily feature of life for those living in the study area. The Nyangatom have ongoing conflict with several of the neighboring populations. The conflicts involve the use of automatic weapons, including Kalashnikovs that were introduced in the late 1980s and are used throughout the region. Similar to other pastoralist groups in the region, the Nyangatom conduct raids that involve a small number of men who attempt to capture livestock with minimal risk. Our data focus on these small raids, ethnographically most similar to those among evolutionarily relevant groups such as mobile foragers.

Raids have a very low mortality rate because raiders seek to seize livestock using ambush and stealth and do so only when there is little risk to themselves. If they cannot find an opportunity with low risk, they will generally abandon their plans and the raid is then unsuccessful. In some cases, dehydration may cause death on raids, but no such instances occurred during the study. During the research period, no subjects were killed or wounded from their participation in a stealth raid. However, deaths for participants do occur. After the conclusion of data collection, one of leaders of this population was killed while on a raid. The raiding party attacked what appeared to be only few enemy herdsman. In fact, there was a larger party of enemies resting nearby who quickly joined the fight resulting in the death of one member of the Nyangatom raiding party.

Raids usually have informal leadership. This usually occurs when an individual decides to initiate a raid and he may then spend several days recruiting other individuals to join him. In some cases, he may visit the village of his desired coraiders over a period of several days to convince them to go. In other cases, raids emerge after age group events in which large cohorts of men from the same age group are congregated.

During the study period, no commercial or political elements to the conflict were observed or described for the motivations of participating in conflict; thus, the circumstances under study seem appropriate as an ethnographic example of small-scale nonstate warfare.

Conflict History Data. Since conflict is a regular feature of Nyangatom life it is discussed openly. It is common for individuals to publicly recount their participation or the participation of their peers. Conflict data were obtained through interviews with study participants about their participation in intergroup conflict events. Coparticipants were identified by the use of the facial photograph sheets. Composition was validated through peer reports with other participants, allowing confirmation of membership for each raiding party. In some cases, the researcher was unable to confirm coparticipant identity, usually because they were not members of the study population. These
individuals were coded as nonsubjects, and no information was obtained about them.

Leaders were identified through interview questions with raid participants about whether any person was a leader on a particular raid. The subject participated in using one of the two words for leader (singular Ekankon; singular Eketamuun). Leadership was validated by reports from more than one raid participant not including the leader himself. This resulted in the identification of five leaders on 19 of the 39 raids. There were six additional cases where three of these five individuals were indicated as being more than a mere participant in raids in which they were not named as a “leader,” either by contributing tactical advice or selecting the location of the raid. However, because they were not identified with the locally used referents for leaders, we excluded these six cases.

We do not present specific individual contributions to raids, incidents of defection, or the outcome of the raids. Instead, we focus here on the presence or absence of any individual from the subject population in each raid.

Other Data. We collected a variety of other data on study participants, as shown in Dataset S1, Table S1.

Anthropometry. Body weight (in kilograms) and height (in centimeters) were measured in the field for all available subjects. Weight was measured using an electronic scale and height measured with a stadiometer. Fifteen subjects were unavailable during the anthropometric data collection and are excluded from such analyses.

Sibling relationships. Sibling relationships were collected as part of the demographic and genealogical data collection for the study population. They were elicited through interviews with subjects, in which they were asked to identify their siblings and whether any of their siblings were among the subjects participating in the study.

Paternal wealth rankings. Among the Nyangatom, men who are not elders seldom own more than a few head of livestock themselves. Rather, livestock are generally owned by elder male family members. Thus, measures of individual wealth are not culturally appropriate for the men in our sample. We used measures of paternal wealth to explore the relationship between the wealth of a raider’s father and raiding-party composition. Paternal wealth rankings were obtained for a subset of the study participants (n = 42). These scores were generated from a ranking task in which elder men (raters)—who were not in this sample—were asked to sort facial photographs of subjects into three piles based on the relative wealth of the father. They were initially asked to identify any men featured in the photographs that they did not know. If they could identify all of the individuals in the photographs, they were then asked to look at the photographs and determine whether they knew the father of the individual in the photograph. Six elders successfully identified all subjects and their fathers and provided the rankings of paternal wealth.

Raters were instructed that they would sort the photographs into three piles based on information about the fathers of the individual featured in the photograph. They were told that in one pile they were to place the photographs of the men who had the wealthiest fathers. They were then told that a second pile was for the men whose fathers had the least wealth. The final pile was situated between the wealthiest and the least wealthy, and raters were instructed to place the photographs of the men who were between the wealthiest and least wealthy into this pile.

Each individual was ranked six times. Each time a subject was placed in the wealthiest pile, they received a score of 3; each time they were placed in the middle pile, they received a score of 2; and each time they were placed in the least wealthy pile, they received a score of 1. The maximum any subject could receive was a wealth ranking score of 18 and the minimum of 6.

Friendship network data. Study participants were asked to participate in a gift allocation task that was used to generate the friendship network. During this task, they were presented with three pieces of candy. Because the population has only minimal access to a market economy, novelty food items, such as candy, are valued. Study participants were presented with the two photo sheets containing the photographs of all 91 study participants. They were asked to make anonymous allocations to three individuals who they desired to receive candy and whose picture was featured on the photo sheets. They were told to do so by placing a piece of candy on the photograph of the subject. Self-allocations and multiple allocations to the same subject were not allowed. Subjects were informed that these allocations would be made at the conclusion of the study but that the identity of the donor would remain anonymous. These allocations were used to generate the friendship network data. Distribution of the candy based on the gift allocations was conducted after the completion of this study element.

We counted the number of times each person was nominated as a friend in the friendship network; this simple measure is called “in-degree.” We also used the nominations to map the full friendship network, and to calculate other social network measures (see below).

Age group membership. Although Nyangatom have generation sets and age sets, age groups are more important in daily interaction than generation or age sets. However, age groups are not panethnic among the Nyangatom, and, in contrast to age sets, members of an age group can come from any generation. At the time of study, adult men who had not yet become ekakout (elders) belonged to one of two age groups. Interviews with subjects collected data on the subject’s territorial section, generation set, and age group.

Using the edge-betweenness algorithm for community detection (53), we find that the vast majority of nodes (98%) are appropriately classified as belonging to their self-identified age group. Moreover, the network can be seen to be composed of two communities (Fig. S1). This provides external validation of the validity of the gift task as a measure of social ties within the Nyangatom community.

Characterizing Whether Raid Participation Is Due to Chance. First, we identify whether raid group participation is due purely to chance using two methods: a \( \chi^2 \) test on simulated data and a permutation test. For the \( \chi^2 \) test, we have the null hypothesis \( H_0 \) that people are drawn uniformly, that is,

\[
Pr(\text{drawing person 1}) = Pr(\text{drawing person 2}) = \ldots = Pr(\text{drawing person 91}).
\]

The alternate hypothesis \( H_1 \) is that not all people have the same probability of being drawn for a raid. We calculate the probability (under the null hypothesis of uniformity) of person \( i \) being drawn in raid \( r \), where raid \( r \) has the observed number of participants \( n_r \). We find that

\[
Pr(\text{person } i \text{ being drawn in raid } r) = \frac{\binom{91 - 1}{n_r - 1}}{\binom{91}{n_r}} = \frac{n_r}{91},
\]

and summing over all raids yields the expected number of observations,

\[
E_i = \sum_{r=1}^{39} \frac{n_r}{91},
\]

and hence the \( \chi^2 \) statistic,

\[
\chi^2 = \sum_{i=1}^{91} \frac{(O_i - E_i)^2}{E_i}.
\]

Performing the \( \chi^2 \) test allows us to reject the null hypothesis at \( P << 0.001 \).
We cross-validated this approach using a permutation test with synthetic data. A dataset was generated to have the same number of participants in each raid (to account for different costs and benefits associated with each) but with people having equal probability of being chosen in a raid. Here, the null hypothesis \( H_0 \) is that the two datasets come from the same distribution, and the alternate hypothesis \( H_1 \) is that the two datasets do not come from the same distribution. We pool the data, permute the observations, split into two groups of the same sizes as the original, and calculate the statistic of interest from these new data. The simulation was run \( 10^6 \) times to obtain the null distribution of the statistic. As a natural statistic of interest, we choose the following:

\[
S = \frac{\sum_{i=1}^{n} |\Delta O_i|}{91},
\]

where \( \Delta O_i \) is the difference of the total number of observations of person \( i \) among the two groups. Comparing with the original statistic using the observed group and the initial synthetic data, we find that \( P \ll 0.001 \), which is sufficient to reject the null hypothesis. Therefore, we conclude that raid group participation is not simply due to chance.

**Identifying Leaders Directly from the Raid Participation Data.** We find a minimal set of raiders that account for participation in all raids. To facilitate this, we use a simple algorithm to establish an upper bound:

1. Calculate the number of raids in which each person participated.
2. Find the person who participated in the most raids.
3. Mark the raids in which he participated and remove those raids.
4. Repeat from step 1 until all raids have been removed.

We find that the five ethnographically identified leaders form precisely such a set (see Fig. 1B, which shows that every raid has at least one leader identified in this manner).

To test that this is a minimal set, we reduce the search space and enumerate all possibilities in the search for a four-person (smaller) set, \( M \). We used a counting argument to reduce the search space. Suppose no ethnographically identified leaders are present in \( M \), then the four most active allowed participants only participated a total of 26 times (7 + 7 + 6 + 6). Even if they joined completely disjoint raids, this is not sufficient to account for all 39 raids. Therefore, at least one leader must be present in \( M \). If exactly one leader is present, the same argument shows that the maximum possible number of raids accounted for is 36. This simple argument shows that at least two ethnographically identified leaders must be present in the proposed set \( M \). We enumerate all of the allowed possibilities and do not find such a set, so we conclude that the ethnographically identified leaders indeed form a minimal set.

This analysis also suggests that raid participation data alone would have helped us to identify the leaders that were identified via questions about leadership.

**Friendship Network Structure.** Although direct comparisons of network datasets are difficult due to different contexts, different ways of ascertaining social connections, and structural differences themselves (e.g., differing network sizes, differing numbers of edges), some comparison of statistics is still informative. In the main text, we present measures of reciprocity, transitivity, and assortativity (homophily) based on degree and age, and discuss the characteristic ways that the Nyangatom social network resembles and differs from simulated random networks and other network data published previously. We find that the degree distribution of the Nyangatom social network was not significantly different from an Erdos-Renyi random network with an identical number of nodes and edges, although the other properties were different in a way similar to several modern networks; in particular, reciprocity, transitivity, and degree assortativity were significantly larger than in random networks, consistent with measures given in prior work (33). As there are multiple related definitions for these measures used in the literature, here we provide formulas for the way our calculations were performed.

“Reciprocity” (the probability that person B is nominated as a friend by person A given that person A is nominated by person B) was measured as the proportion of mutual connections. That is, given connectivity matrix \( A \),

\[
\text{Reciprocity} = \frac{\sum_{i,j} a_{ij}a_{ji}}{\sum_{i,j} a_{ij}}.
\]

“Transitivity” (the likelihood that two of a person’s friends are themselves friends) is calculated as a global network parameter, that is, the ratio of connected triples to the total number of possible connected triples in the graph.

To calculate assortativity (“homophily”—the probability of nodes with similar characteristics being connected), we first assign values of interest to the nodes (degree, age group). Let \( e_{ij} \) be the fraction of edges connecting nodes of type \( i \) and \( j \), let \( q_i^{(1)} = \sum e_{ij} \), \( q_i^{(2)} = \sum e_{ji} \), and let \( \sigma^{(1)} \), \( \sigma^{(2)} \) be the SDs of \( q_i^{(1)} \), \( q_i^{(2)} \), respectively. Then, we calculate homophily as follows:

\[
\text{Homophily} = \frac{\sum_{i,j,k} A_{ijk} \left( e_{ij} - q_i^{(1)} q_j^{(2)} \right)}{\sigma^{(1)} \sigma^{(2)}}.
\]

“Eigenvector centrality” assumes that the centrality of a given individual is an increasing function of the centralities of all of the individuals to whom he or she is connected. Although this is an intuitive way to think about which subjects might be better connected, it yields a practical problem—how do we simultaneously estimate the centrality of all subjects in the network? Let \( a_{ij} \) equal 1 if subjects \( i \) and \( j \) have a social connection and 0 if they do not. Furthermore, let \( x \) be a vector of centrality scores so that each subject’s centrality \( x_i \) is proportional to the sum of the centralities of the subjects to whom they are connected: \( x_i = a_{1i}x_1 + a_{2i}x_2 + \cdots + a_{ni}x_n \). This yields \( n \) equations, which can be represented as \( Ax = \lambda x \). The vector of centralities \( x \) can now be computed because it is an eigenvector of the eigenvalue \( \lambda \). Although there are \( n \) nonzero solutions to this set of equations, in symmetric matrices, the eigenvector corresponding to the principal eigenvalue is used because it maximizes the accuracy with which the associated eigenvector can reproduce the original social network. To be sure of reaching a solution, we symmetrized all asymmetric relationships in the observed network (i.e., we assumed all friendship ties were mutual).

**Modeling Individual Characteristics.** In this section, we describe methods to explore what individual characteristics are associated with raid participation, leadership, and network in-degree.

Dataset S1, Tables S2–S7, shows linear regressions that measure the association between raid participation and various individual characteristics. The basic model is the following:

\[
E[Y_i] = \alpha + \beta x_i,
\]

where the dependent variable \( Y \) is the total number of raids in which person \( i \) participated, \( x_i \) is a vector of individual characteristics for participant \( i \), and \( \beta \) is a vector of coefficients that indicate the degree of association with each characteristic. The specific independent variables are height (in centimeters), weight (in kilograms), number of siblings (paternal or maternal), and paternal wealth (only measured for \( n = 42 \) people). Models are calculated for the full population (left side of tables) and for the subset of the population...
who are not leaders (right side of tables). Only the significance of in-degree (net of sibling contributions, which are measured separately) remains for both the full population and the population that does not include leaders when all individual characteristics are allowed. These models suggest that social information is more important for raid participation levels than individual characteristics. As the physical egocentric variables are no longer significant when in-degree is added, there may be a path from these variables to in-degree and leadership status, which will be explored in future work. We used ordinary least squares regression to estimate these models, but count models yielded similar results.

Dataset S1, Tables S8–S12, shows a similar set of models, but the dependent variable $Y_i$ is the in-degree of person $i$ (net of siblings). Siblings, paternal wealth, and leadership status individually appear to be significantly associated with raid participation in both the full population and the subset of the population that does not include leaders.

Finally, Dataset S1, Table S13, shows a similar model, but the dependent variable $Y_i$ is the eigenvector centrality of person $i$ (net of siblings). This regression shows that even when controlling for the number of direct contacts, leaders tend to have higher centrality, suggesting that leaders not only have more friends, but their friends are more popular and they have more friends of friends as well.

**Models with Raid and Social Information and Fixed Effects.** In this section, we describe methods to explore associations between raid characteristics and raid participation.

Dataset S1, Tables S14–S20, shows linear regressions that measure the association between an individual’s decision to join a particular raid and various raid characteristics. The basic model is the following:

$$E[Y_{ir}] = \alpha + \theta_i + \gamma_r + \beta x_r,$$

where the dependent variable $Y_{ir}$ is 1 if person $i$ joins raids $r$, and 0 otherwise; $\alpha$ is a constant (dropped if fixed effects are included); $x_r$ is a vector of characteristics for participant $i$ and raid $r$; and $\theta_i$ and $\gamma_r$ are individual and raid fixed effects, respectively.

Fixed effects are included to control for variation in stable characteristics across individuals (e.g., are some individuals inherently more likely to join raids?) and across raids (e.g., are some raids inherently more important?). This approach effectively controls for all possible stable individual and raid characteristics. For example, it ensures that personal differences that may impact the tendency of a person to engage in risky behavior or differences that may impact the importance of a raid are not driving the results.

Additionally, because there are multiple (and probably correlated) observations for both raids and individuals, we adjust SEs by clustering them on both raids and individuals using multiway clustering (54).

Dataset S1, Tables S14 and S15, shows regressions of raid participation on the total number of leaders and nonleaders who joined the raid. Although Dataset S1, Table S14, shows that the number of nonleaders participating is significantly associated with the decision to join, when we control for individual fixed effects in Dataset S1, Table S15, the association ceases to be significant. Because neither the number of leaders nor the number of nonleaders survives both specifications, we turn to models based on participation by friends rather than total participation.

Dataset S1, Tables S16–S18, show regressions of raid participation on social aspects of raid composition. Dataset S1, Table S18, shows the strictest specification with both raid and individual fixed effects. As discussed in the main text, the number of first-degree leaders, first-degree friends, and second-degree friends on a raid are all significantly associated with raid participation, and these results survive multiple model specifications and strong controls for fixed individual and raid characteristics.

Dataset S1, Table S19, shows a regression of raid participation on the number of siblings also in the raid with and without individual or raid fixed effects. Only in the model without fixed effects is the number of siblings significant. For completeness, we consider the prior (full) model with siblings separated out.

Dataset S1, Table S20, shows a regression of raid participation on the social aspects of raid composition (as in Dataset S1, Table S18) with the further inclusion of the number of siblings who participated on raids. We again find that leaders of distance 1, friends of distance 1, and friends of distance 2 are significant, whereas the number of siblings on raids (net of leader and nonleader friends of distances 1, 2, and 3) is not significant. This again suggests that it is friends, not siblings, that matter for the emergence of violence.

Finally, Dataset S1, Table S21, shows a model that regresses the number of nonleader friends who join a raid on a person’s own decision to join the raid (1 = joined), their leadership status (1 = leader), and an interaction of the two. The results suggest that leaders who join raids actually mobilize significantly fewer individuals to join than nonleaders, and this is despite the fact that leaders tend to have more friends as shown in Dataset S1, Table S12.

Dataset S1, Table S22, shows a model that regresses a person’s own decision to join a raid upon the number of leaders and nonleader friends, both net of siblings, who join a raid. These results support the hypothesis that a friendship relationship is more important than a family (sibling) relationship in deciding to join raids. Again, net of siblings, the first-degree friendship effect is by far the largest determinant for joining raids.

To further test the hypothesis that it is friendship ties, and not family ties, that are important, we performed a permutation test of which raids individuals join, keeping the number per raid and the total number of raids participated in by each individual constant, and we asked what percentage of raids have any sibling pairs. We find that the observed value lies near the center of the distribution of the permuted values, suggesting that siblings do not raid in pairs more frequently than chance, and in line with the regression analysis.

**Network Graphs.** The friendship network was drawn with iGraph in R using the Kamada–Kawai algorithm. Node colors indicate participation status (green, nonparticipants; blue, participants; red, leaders), size is increasing with the number of raids in which a person participated (larger, more active), and arrows indicate gift-giving direction.
**Fig. S1.** Nyangatom social network. Colors denote age group membership (blue, younger age group; green, older age group). Ties within the same group are the same color as the group nodes. Ties between groups are in red. As expected, most friendship ties are within age groups.

**Fig. S2.** Network of friendship ties in Nyangatom society determined using a gift allocation task. Those who did not participate in any raids (nonparticipants) are shown in green, those who participated in at least one raid (participants) are shown in blue, and identified leaders are shown in red. Node size is proportional to raid participation (number of raids in which an individual participated). Dark gray arrows indicate reciprocal, two-way friendship ties, and light gray arrows are one-way ties. Dashed red lines indicate coraiding.

**Other Supporting Information Files**

[Dataset S1 (PDF)](https://www.pnas.org/cgi/content/short/1610961113)