

Highlights

Friendship and partner choice in rural Colombia

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- We provide one of the first detailed quantitative empirical examinations of friendship networks in a rural subsistence setting.
- We find that individuals preferentially assort with those who share similar socio-demographic attributes.
- There are important differences in what predicts friendship ties across groups and economic settings, with the friendship–cooperation nexus being stronger in more marginalized communities.

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Daniel Redhead^a, Augusto Dalla Ragione^a and Cody T. Ross^a

^aDepartment of Human Behavior, Ecology and Culture, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, Leipzig 04103, , Germany

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ABSTRACT

Friendship is a recurring feature of human sociality. Extant evidence has highlighted several axes upon which the formation and maintenance of friendships rest, and has emphasised the importance of market-like mechanisms and preferential assortment in such dynamics. Such evidence has emerged from qualitative ethnographic descriptions, and observational or experimental case studies in relatively homogeneous samples from Western and industrialised settings. Here, we provide one of the first empirical evaluations of the structure of friendship networks in a rural subsistence setting. We collected individual-level friendship network data, and detailed economic and demographic information from individuals from four communities in rural Colombia ($N = 470$). We analyse these data using a combined social relations and stochastic block model. Our results highlight the importance of preferential assortment on the basis of several socio-demographic traits in all study communities. The extent to which friendship and social support networks overlap appears to vary considerably across communities, with greater overlap being observed in more impoverished areas. Similarly, the extent of wealth homophily was greater in more impoverished areas. Such findings suggest that variation in the axes upon which friendship rests may be affected by community-level variation in economic and demographic composition.

1. Introduction

Across cultures, humans frequently form and maintain long-term cooperative relations with individuals who may or may not be genetically related. In many cases, these relationships are established and maintained because they provide benefits to the parties involved—i.e., both individuals support one another with material resources, such as food or money, as well as with non-material resources, like advice and emotional support. We call these broad, multi-faceted relationships *friendships*, following the working definition proposed by Hruschka (2010), who states that friendships are defined by social and material support, and positive affect, between partners. Although there is large variation in how friendship is perceived and sanctioned across cultures, a common core set of features has emerged from the ethnographic record. For example, mutual aid, gift giving, and positive affect are mentioned as recurrent characteristics of friendship in the Probability Sample File, while informality, self-disclosure, and frequent socializing occur only sporadically (Hruschka, 2010). Long-term bonds with non-kin are also present in several non-human animals, and have similarly been termed “friendships”. There is reason to believe that many of the fitness considerations that we outline here may also apply in some non-human species (Brent, Chang, Gariépy and Platt, 2014; Seyfarth and Cheney, 2012).

At a proximate level in humans, interpersonal sentiments are thought to track the fitness-relevant affordances of social relationships—like friendships—and thus regulate

social behaviour (Gervais and Fessler, 2017). For example, feelings of love or liking between two individuals might be up-regulated by mutual support, fitness inter-dependencies, or complementarities in skills, and down-regulated by betrayals, the formation of social ties to distrusted third parties, or changes in the ability of one individual to materially contribute to the relationship (see Fessler and Gervais, 2010, for a detailed discussion). At the same time, interpersonal sentiments also guide social behavior—i.e., rather than deploying tit-for-tat style reciprocation, humans may give to those that they love or like because of a suite of considerations that they have mentally tracked over long periods of time, even if one member of the relationship is transiently unable to provide mutual support (Hruschka and Henrich, 2006). For example, cross-cultural ethnographic evidence suggests that strict bookkeeping between friends is neither prevalent nor normative—both in Western and non-Western settings (reviewed in Hruschka, 2010). Friendships are therefore a type of cooperative relationship in which individuals do not base behaviour on purely reciprocal exchange of resources. Other factors are also important when individuals are considering who to form and maintain social ties with.

In this paper, we review some of the key evolutionary considerations thought to undergird friendships. More specifically, we overview the literatures on market-like dynamics in partner choice and friendship formation, homophily, and network multiplexity. We then investigate if the structure of friendship networks in four rural Colombian populations is consistent with predictions drawn from these literatures. Our analysis draws on novel individual-level, household-level, and network data, and is designed to evaluate whether the structure of friendships in this setting is consistent with theoretical mechanisms thought to influence partner choice more broadly.

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*Corresponding author

✉ daniel_redhead@eva.mpg.de (D. Redhead); cody_ross@eva.mpg.de (C.T. Ross)

ORCID(s):

1.1. Friendship markets

Theory has suggested that the structure of friendship networks may be guided in-part by partner choice dynamics operating in market-like environments (Barclay, 2016; Noë and Hammerstein, 1994; Roberts, 1998). Within such ‘biological’ markets, individuals exchange commodities (e.g., goods or services that are functionally beneficial) with one another. The value of such commodities, and the social relationships that afford access to them (Lin, 2001), may be a source of competition between individuals, and individuals may therefore compete with one another through altruistic behaviour or agonistic contest to gain such social ties (Noë and Hammerstein, 1995). The core characteristics thought to underlie partner choice in these markets are thus: 1) the ability to confer benefits to others, 2) the willingness to confer such benefits, and 3) availability as a social partner (i.e., there are constraints on how many cooperative partners an individual can maintain; Barclay, 2013; Redhead, Dhaliwal and Cheng, 2021).

Given this, individual differences in traits that signal or cue the ability to confer benefits to others (e.g., “resource holding potential”; Maynard Smith and Parker, 1976) are a defining feature of partner choice. The ability to confer benefits further rests upon the social and ecological contexts in which cooperation is embedded. For instance, in contexts where subsistence is based on hunting and foraging, an individual’s skill and knowledge related to these activities may be especially important for choosing who to associate with (Smith, Hill, Marlowe, Nolin, Wiessner, Gurven, Bowles, Borgerhoff Mulder, Hertz and Bell, 2010). Socio-ecological considerations may not only be relevant in determining the qualities that become most important to partner choice, but might even modify the incentive structure governing whether or not individuals invest in friendship ties at all. There may, for example, be strong incentives to rely on friends as informal sources of social support in contexts where formal institutions are dysfunctional or corrupt (De Sardan, 1999), environmental variation is high (Winterhalder, 1986), and poverty or resource constraints prevalent (Pisor and Gurven, 2016). Similarly, the importance of friendships may weaken or dissolve as individuals gain material security from other sources—for example, when immigrants from the former USSR migrated to the USA, the nature of their social relationships changed (Hruschka, 2010; Markowitz, 1991).

Alongside macro-level material and socio-ecological factors, there are often individual-level attributes that affect partner choice in friendship networks. Such personal qualities often center on culturally-valued and/or age-related attributes—such as attractiveness (Langlois, Kalakanis, Rubenstein, Larson, Hallam and Smoot, 2000) or status (Power and Ready, 2018; Redhead, Cheng, Driver, Foulsham and O’Gorman, 2019). Such attributes need not be reliably associated with actual ability or material security, but may instead be conventionally assigned badges of *perceived* value (Redhead and Power, 2022). Physical appearance, for instance, seems to influence individuals’ choice of friends,

as being perceived as connected to physically attractive individuals affords more positive impressions (Eagly, Ashmore, Makhijani and Longo, 1991; Riggio, 1986). However, both theory and empirical evidence suggests that individuals often attempt to establish ties with valued or high-status individuals, because such connections do provide the ability to access and mobilize the personal resources and/or social connections of these high-status ties (Lin, 2001; Thye, 2000; von Rueden, Redhead, O’Gorman, Kaplan and Gurven, 2019).

Although individuals with material resources or high social status may be better poised to gain many social connections, they must also be willing to confer benefits upon others for cooperative relations to form. For instance, children who provide positive reinforcement to others are often more socially accepted themselves (and, conversely, negative reinforcement is associated with social rejection; Hartup, Glazer and Charlesworth, 1967). Consequently, individuals who signal their willingness to help others can gain a return in terms of social standing among their peers, increasing the likelihood of them being supported rather than excluded or exploited by others (Bhui, Chudek and Henrich, 2019). Variation in prosocial tendencies, coupled with partner choice dynamics, can lead to an escalation of generosity—where altruistic individuals will tend to associate with similarly altruistic agents, ostracizing cheaters/defectors (Roberts, 1998).

The demand characteristics described above could lead to expectations that individuals highest in a culturally-valued attribute would be universally nominated as friends. However, supply-side constraints in a market will often limit the feasible set of ties for the fraction of the population lowest in a given, socially valued, attribute (Jackson, 2010). For example, the poorest people in a given community might desire to form ties with wealthy individuals, but those same wealthy individuals may see little potential benefits to be gained from associating with others far below themselves in socio-economic standing (Gould, 2002). Such market-like dynamics are expected to constrain individuals to associate with others similar to themselves. That is, market-like mechanisms can lead friendship networks to exhibit patterns of *homophily* on the basis of key attributes, especially status and wealth.

1.2. Homophily

Beyond market-like dynamics based on resource control and provisioning, partner choice is also influenced by other forms of assortment. For example, the tendency of individuals to associate preferentially with those who share similar characteristics has been repeatedly documented in the literature (McPherson, Smith-Lovin and Cook, 2001). Such preferential attachment may function to promote effective coordination, as similar attributes can signpost shared norms and expectations of behaviour (Carley, 1991; Mayhew, McPherson, Rotolo and Smith-Lovin, 1995). Theoretical models of cultural evolution have shown that individuals may benefit from preferentially imitating the behavioral traits expressed by others who share their own symbolic markers (Boyd and

Richerson, 1987). McElreath, Boyd and Richerson (2003) have extended these models, and demonstrated that symbolic markers (e.g., of ethnicity or religion; Barth, 1969) can emerge in contexts where there are benefits to coordination, and the covariance between markers and behavioural norms is positive.

Empirically, humans tend to exhibit altruistic cooperation directed towards members of the same ethnic group, coupled with some degree of out-group hostility or animus (Fearon and Laitin, 1996; Bowles, 2008). However, the intensity and prevalence of such social predispositions appears to vary, sometimes substantially, across human groups and across contexts (de Dreu, Balliet and Halevy, 2014; Böhm, Rusch and Baron, 2020). Social assortment on the basis of group identity often appears more pronounced, for example, when there are clear power differentials between individuals as a function of ethnic background (Waring and Bell, 2013; Waring, 2012).

Religious identity may also structure social relationships, such that individuals interact and cooperate more with those who share their religious beliefs (Lang, Purzycki, Apicella, Atkinson, Bolyanatz, Cohen, Handley, Kundtová Klocová, Lesorogol, Mathew et al., 2019). The empirical evidence that people preferentially select their social partners on the basis of conspicuous religious behaviour is, however, also mixed (Oviedo, 2016). For instance, religion may be more important for structuring friendships in small but vigorous social movements than for structuring friendships in more established settings (Bainbridge and Stark, 1981; Stark, 1992).

Homophily has also been observed for a variety of other attributes, including physical attractiveness, political orientation, education level, body size, and wealth. For example, partner choice in online dating platforms appears to be structured by homophily in political opinion, physical attractiveness, and educational attainment (Huber and Malhotra, 2017; Skopek, Schulz and Blossfeld, 2011; Fiore and Donath, 2005). There is further empirical evidence that friendship ties are regularly structured on the basis of age (Verbrugge, 1977; Marsden, 1988) and body mass index (De La Haye, Robins, Mohr and Wilson, 2011; Christakis and Fowler, 2007), and that social class and occupation shape the structure of friendship and other types of social networks (McPherson et al., 2001; Wright, 1997).

1.3. Multilayer networks

Individuals operate within multiple, overlapping kinds of social relationships in their daily lives. For instance, individuals may be linked in friendship networks, kinship networks, cooperation networks, and/or coworking networks, and ties in one layer may change the probability of ties in another (Nicosia, Bianconi, Latora and Barthelemy, 2013; Redhead and von Rueden, 2021). For example, individuals may be more likely to provide social or material support to their friends or relatives, than to acquaintances or strangers (Barclay, 2016; O’Gorman, Wilson and Miller, 2005). Conversely, individuals may be more likely to consider those

who have provided social or material support as friends (Hruschka, 2010). Survey-based research has shown that a non-trivial proportion of individuals nominated as friends are also relatives, and that those nominated as both friends and kin are more likely to provide (different types of) support (Bush, Walker and Perry, 2017). This suggests that friendship networks should be structured by ties in other network layers.

How such overlapping networks are structured, however, depends on their form and content, and on cultural and ecological context. Indeed, while theoretical accounts highlight the role that reciprocal altruism (i.e., the mutual exchange of material resources or social support) plays in structuring cooperation (broadly defined; Axelrod and Hamilton, 1981; Nowak, 2006; Trivers, 1971), cooperative relations can be unbalanced across many domains and contexts. Moreover, there may be between-layer exchanges, in which one type of support flows in one direction in given network layer, but reciprocation occurs in a different layer. For instance, relatively low levels of reciprocity are both expected—due to imbalances in foraging skill and/or differences in resource control—and observed in food sharing networks in many small-scale subsistence settings (Koster and Leckie, 2014; Nolin, 2010a; Ready and Power, 2018; von Rueden et al., 2019), but such unbalanced flows may be reciprocated in other currencies (such as social or political support; Redhead and von Rueden, 2021).

Additionally, the linkage between friendship and support networks may be affected by other processes, such as kin selection (i.e. family provisioning; Hamilton, 1964), costly signaling (i.e. showing off one’s own skills; Bliege Bird, Smith and Bird, 2001), tolerated scrounging (when food cannot be easily controlled; Blurton Jones, 1987), and needs-based giving (Cronk, Berbesque, Conte, Gervais, Iyer, McCarthy, Sonkoi, Townsend and Aktipis, 2019). Taken together, friendship ties should be associated with ties in other networks, such as kinship networks, food sharing networks, and experimental cooperation networks. However, the extent of such overlap may be affected by the local context (i.e., friendship and social support networks may covary more tightly in contexts of poverty, than in other contexts).

1.4. The current study and predictions

The current study aims to examine the factors that shape friendship networks in a set of rural Colombian communities. In Table 1, we present a list of predictions about the many relevant factors that influence the structure of friendship ties. These predictions are based on the body of theoretical work outlined above, and link the probability of friendship nominations to individual-level characteristics (e.g., physical attractiveness, wealth, and education level), dyad-level characteristics (e.g., relatedness, spatial proximity, and dyadic sharing ties), and block-level characteristics (e.g., ethnic group, religion, and sex).

In the section that follows, we provide details on the ethnographic context of our study, the data collection protocols used to elicit outcome and covariate data, and the statistical methods used to evaluate our predictions.

2. Methods

2.1. Ethnographic setting

We collected data in four rural Colombian communities: a Coastal Afrocolombian/Emberá site (henceforth referred to as the ‘Coastal site’, $n = 117$), a lowland Afrocolombian/Emberá site (the ‘Lowland site’, $n = 151$), a highland Mestizo site that borders the lowland site (the ‘Highland site’, $n = 66$), and a final Mestizo site in the Colombian Altiplano (the ‘Altiplano’ site, $n = 136$). Each community was sampled as completely as possible within a pre-demarcated geographic area; in the Coastal, Lowland, and Highland sites, nearly all households in the census area opted into the study, and in the Altiplano site about three-quarters of households opted in. We invited all adult residents within the census area to participate in the study, and no further selection criteria were applied.

The data presented here were collected by CR and local research assistants, as part of a wider, longitudinal field study on wealth inequality, demography, and social network structure (see Koster, Power, Redhead, Borgerhoff Mulder, Bowles and Jackson, 2017). Informed consent was obtained from each respondent prior to data collection, and from the community leader or local community council, when appropriate. Due to limited literacy rates, informed consent was obtained verbally after providing respondents with a verbal description (in Spanish) of the research process and explaining how their data will be used (anonymously, for research purposes); in addition, participants were provided with a written consent document for their own reference. All field protocols were approved by the Department of Human Behavior, Ecology, and Culture at the Max Planck Institute for Evolutionary Anthropology in Leipzig Germany.

At both Afrocolombian sites (Coastal and Lowland), the population is composed of a majority of Colombians of African descent, along with minorities of Mestizos and indigenous Emberá. At both Mestizo sites (Highland and Altiplano), however, the population is almost entirely Mestizo. The Coastal and Lowland communities, like many others in the region, have been heavily affected by Colombia’s internal conflicts, and violence from guerilla and paramilitary groups—especially in the late 1990s and early 2000s (OCHA, 2012a,b). The Highland site lies on the boundary of territory that was once occupied by guerillas, while the Altiplano site is distant from such conflict zones. A large proportion of residents in the Afrocolombian sites are considered internally displaced persons within Colombia, and have resettled after being forced from their natal communities (Pisor, Gervais, Purzycki and Ross, 2020).

Subsistence and labor practices are quite variable across sites. The Coastal community relies on fishing and local wage labor for subsistence. There are, however, limited

levels of hunting, horticulture, and animal husbandry, as well. The Lowland community is located in the rain-forests of western Colombia, and subsistence is based on a mixture of horticulture, local wage labor, hunting, animal husbandry, and artisanal gold panning. The economy of the Highland community is based on small-scale agricultural production of coffee and sugarcane. Finally, the economy of the Altiplano community is based primarily on wage labor, especially in companies focused on large-sale flower cultivation. Each community is characterized by some level of poverty relative to more urbanized areas in Colombia, especially the Coastal and Lowland sites—which are predominantly Afrocolombian.

2.2. Methods and measures

Here, we outline the field-methods used to obtain the data analyzed in this study.

2.2.1. Network data

Community-wide censuses were taken in 2016–2017 (Coastal and Lowland sites) and in 2018–2019 (Highland and Altiplano sites) to obtain social network data. During these censuses, data on friendships and resource transfers were collected using self-report “name-generator” interviews (Marsden, 1990). Data on friendship ties were elicited by asking respondents to name the people that they have “*spent the most time socializing with*” in the 30-day period prior to the interview. Descriptive statistics about the friendship networks in each site are reported in Table 2, and visual depictions of the networks are plotted in Figure 1. Data on food/money transfers were elicited by asking respondents to name: (i) the people that they have “*given food/money to*”, and (ii) the people they have “*received food/money from*”, in the 30-day period prior to the interview. CR then linked unique identifiers to the names that were elicited using the “name-generator” questions; the data were reviewed numerous times to find and remove duplicates and collisions, in a process known as entity resolution (Talbur, 2011). In the food/money transfer network, ties were coded as present if either individual in a given dyad reported the transfer. Table 3 presents the descriptive statistics on such sharing networks.

2.2.2. RICH economic game data

To supplement the social network data with behavioral measures of generosity and exploitation, we use two RICH economic games (Gervais, 2017) run in 2017–2018 (at the Coastal and Lowland sites) and in 2018–2019 (at the Highland and Altiplano sites); due to some out-migration, the sample sizes of the economic game data (and the final data used in the analyses) are slightly smaller— $n = 93$ Coastal, $n = 135$ Lowland, $n = 56$ Highland, and $n = 109$ Altiplano. RICH economic games involve tasks where participants (often called deciders or focals) have a chance to: (i) allocate money to, (ii) take money from, and (iii) at a cost to themselves, reduce the payouts of other individuals (a.k.a., alters). In these games, a photograph roster is used to allow each focal individual to make decisions with respect to each other person in the study (see Ross and Redhead, 2021,

Table 1: Predictions and variables

Prediction	Level	Explanation	Associated variables	References
1) There will be positive and reliable estimates of dyadic and generalized reciprocity	Dyadic	Friendship nominations should reflect an underlying network of relations. As such, we expect concordance in nominations between any two given individuals. Nonetheless, we do not expect perfect concordance, as some nominations may be aspirational, and past empirical work has shown some degree of asymmetry in friendship nominations.	Friendship nominations	Ball and Newman (2013); Ready and Power (2021)
2) Individuals with a high potential to confer benefits to others will receive more friendship nominations	Individual	Individuals who score high on dimensions positively associated with resource holding potential will receive more friendship nominations.	Attractiveness, BMI, grip strength, wealth	Barclay (2016); Eagly et al. (1991); Riggio (1986)
3) Individuals with the propensity to help others will receive more friendship nominations	Individual	The willingness to confer benefits to others is a valued attribute in a social partner.	RICH allocation and RICH exploitation	Gervais (2017); Roberts (1998)
4a) Individuals will prefer to form in-group ties as opposed to out-group ties	Block	Preferential attachment on the basis of categorical characteristics can minimize miscoordination.	Religion, ethnicity, gender	McElreath et al. (2003); McPherson et al. (2001)
4b) Religion and ethnicity will be less salient for individuals belonging to the predominant group in their communities	Block	The salience of ethnicity or religion to partner choice will depend on asymmetries in group size, power, and dominance. For example, Catholics should display lower religious homophily compared to other denominations when they are demographically predominant.	Religion, ethnicity	Bainbridge and Stark (1981); Stark (1992); Hewstone, Rubin and Willis (2002)
4c) People will tend to associate with others who are similar to themselves	Dyadic	Preferential attachment on the basis of continuous attributes can arise from market-like dynamics in partner choice.	Political distance, wealth distance, age distance, educational distance	Johnson and Smirnov (2018); Huber and Malhotra (2017); Marsden (1988); De La Haye et al. (2011)
5) Friendship networks will overlap with other networks associated with cooperation	Dyadic	Many individuals report friendship ties with people they are genetically related to, or that they have established cooperative relationships with.	Relatedness, food sharing, dyadic RICH allocation, and dyadic RICH exploitation	Bush et al. (2017); Hruschka and Henrich (2006); Nolin (2010b); Redhead and von Rueden (2021)

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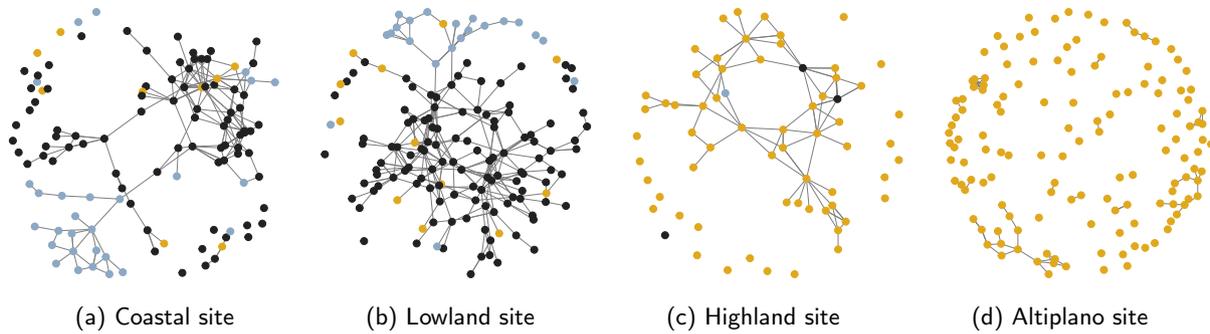


Figure 1: Network structure. Afrocolombians are plotted in dark-grey, Emberá in blue, and Mestizos in goldenrod. There is substantially more community structure in the Afrocolombian/Emberá sites (Coastal and Lowland) than in the other sites. In the Mestizo sites (Highland and Altiplano), there are fewer friendship nominations to in-community alters. This is especially true in the more market-integrated Altiplano community, where a predominance of wage labor leads most individuals to name out-of-community individuals (especially coworkers), rather than in-community neighbors as friends.

Table 2
Network descriptive statistics for friendship nominations

Site	Size	Ties	Density ^a	Reciprocity ^b	Transitivity ^c	Mean degree	In-degree range	Out-degree range
Coastal	117	177	0.013	0.282	0.244	1.513	0 - 9	0 - 9
Lowland	149	262	0.012	0.252	0.197	1.758	0 - 7	0 - 8
Highland	65	86	0.021	0.302	0.226	1.323	0 - 5	0 - 8
Altiplano	136	68	0.004	0.265	0.437	0.5	0 - 5	0 - 4

Notes. ^aNetwork density represents the proportion of actual ties (here, friendship nominations) with respect to the total number of possible ties. ^bReciprocity shows the proportion of reciprocated ties with respect to the number of existing ties. ^cTransitivity represents the fraction of closed triples with respect to the total number of triples.

for details and software tools). The two RICH games used here—the allocation and exploitation games—have important differences in framing. In the giving/allocation game, deciders are given a small number of tokens/coins, which they can either keep for themselves or allocate across alters. In the taking/exploitation game, one token/coin is placed on the photo of each alter; deciders can leave these coins in place or take them for themselves by engaging in exploitative behavior. For clarity, we reverse-code the taking/exploitation game as a leaving game, so that positive values represents positive ties.

The stakes per person for the RICH allocation game were set at 15,000, 20,000, 10,000, and 10,000 Colombian pesos (approximately 3–7 USD) in the Coastal, Lowland, Highland, and Altiplano sites, respectively. Individuals could allocate any number of 1,000 peso coins to any cell in the photo array, including their own. The stakes per person for the RICH exploitation game were set at 58,000, 75,500,

33,000, and 70,000 Colombian pesos (approximately 11–25 USD) in the Coastal, Lowland, Highland, and Altiplano sites, respectively. Individuals could take or leave the single 500 peso coin pre-allocated to each photo in the array.

Dyadic measures of giving and leaving were constructed by creating an adjacency matrix from the raw edge-list data of coin transfers. Individual-level giving and leaving propensities were measured by calculating how many coins a focal gave to (or left for) all other alters.

2.2.3. Attractiveness data

Attractiveness was measured using the RICH photograph roster. Each individual was given up to 8 tokens (per sex) and asked to indicate who on the roster was most (physically) attractive. Respondents independently rated males and females. Though the prompt emphasized physical attractiveness, respondents did tend to mention (in debriefing interviews) that other factors (like goodness, kindness, and

Table 3
Network descriptive statistics for sharing ties

Site	Size	Ties	Density	Reciprocity	Transitivity	Mean degree	In-degree range	Out-degree range
Coastal	117	135	0.01	0.478	0.098	1.154	0 - 11	0 - 9
Lowland	149	122	0.006	0.098	0.112	0.819	0 - 4	0 - 5
Highland	65	30	0.007	0.067	0.086	0.462	0 - 3	0 - 3
Altiplano	136	41	0.002	0.537	0.2	0.301	0 - 2	0 - 3

willingness to help others) influenced their attractiveness ratings. The attractiveness scores here represent the number of times that a given alter was rated as one of the most attractive community members by raters of either sex.

2.2.4. Background socio-demographic data

Socio-demographic surveys were conducted in 2016–2017 at the Coastal and Lowland sites, and in 2018–2019 at the Highland and Altiplano sites. As part of these interviews, each individual in each community was asked to give their (self-reported) age, self-ascribed gender, self-ascribed ethnic identity, and self-ascribed religious identity. Additionally, individuals completed an interview about their opinions on various, potentially polarizing social issues (like the Colombian peace accord, legalized abortion, the legality of same-sex marriage, and the legality of marijuana).

2.2.5. Reproduction and relatedness data

Reproductive history interviews were also conducted in 2016–2017 at the Coastal and Lowland sites, and in 2018–2019 at the Highland and Altiplano sites. As part of these interviews, each individual in each community was asked to name all parents, children, and siblings. Reproductive success (RS) is defined here as the number of surviving offspring of each focal individual. Relatedness between each pair of individuals was calculated by constructing a pedigree from parent-offspring trio data, which was then used to create a pairwise matrix of relatedness values.

2.2.6. Wealth and well-being measures

Wealth and well-being surveys were conducted in 2016–2017 at the Coastal and Lowland sites, and in 2018–2019 at the Highland and Altiplano sites. During these surveys, a variety of data were collected on wealth (broadly conceived; Borgerhoff Mulder, Bowles, Hertz, Bell, Beise, Clark, Fazzio, Gurven, Hill, Hooper et al., 2009), including somatic measures (such as height, weight, BMI, and grip strength), noetic measures (like education), as well as material measures (like the sum value of a suite of common household items). Height and weight were measured using a stadiometer and electric scale, respectively. Grip strength was measured using a hand dynamometer. Education is self-reported years of formal education. The (log) wealth variable used here represents the sum total of the local monetary value of all: vehicles, motorcycles, motorboats, computers, TVs, washing machines, refrigerator, stoves, microwaves, cell phones, cows, pigs, and chickens in the household of the focal respondent.

2.2.7. Distance measures

Some variables, like location, are thought to impact friendship mostly through dyadic effects. In other words, the probability of a friendship tie might decline as the distance between household locations increases in a dyadic sense. As such, we used imagery data to calculate a (normalized) pairwise distance matrix between the households of individuals.

As with spatial distance, the “distance” between individuals in other measures can be relevant to partner choice and

friendship, especially through the mechanism of homophily. Here, “age distance” is the absolute value of the difference in the ages of individuals i and j . Similarly, “attractiveness distance” is the absolute value of the difference in the attractiveness scores of individuals i and j , “BMI distance” is the absolute value of the difference in BMI between individuals i and j , “education distance” is the absolute value of the difference in years of education between individuals i and j , and “wealth distance” is the absolute value of the difference in log wealth between individuals i and j .

As stated in the socio-demographic section (Section 2.2.4.), individuals were also asked if they agree or disagree with: 1) the Colombian peace accord, 2) legalized abortion, 3) legalized same-sex marriage, and 4) legalized marijuana access. The final variable, “political distance”, is measured using the number of questions in which individuals i and j either both agreed with the statement, or both disagreed with the statement.

2.3. Analytical Strategy

To model how various individual-, dyadic-, and block-level covariates are related to the probability of network tie formations, we use a generalization of the Social Relations Model (Kenny and La Voie, 1984; Snijders and Kenny, 1999), which integrates block-level random effects (see Redhead, McElreath and Ross, 2022; Ross, McElreath and Redhead, 2022, for technical outlines and tutorials). Specifically, we estimate the probability of a directed tie between two individuals in the friendship network, F , as a function of: sex, S , ethnic group, E , religious group, R , age, A , physical attractiveness, P , BMI, B , years of education, U , grip strength, G , reproductive success, Q , log wealth, W , RICH giving propensity, Z , RICH leaving propensity, L , dyadic spatial distance, D , dyadic age distance, \bar{A} , dyadic attractiveness distance, \bar{P} , dyadic BMI distance, \bar{B} , dyadic education distance, \bar{U} , dyadic political opinion difference, O , dyadic log wealth distance, \bar{W} , relatedness, K , food/money sharing ties, M , dyadic RICH giving, \bar{Z} , and dyadic RICH leaving, \bar{L} .

The overall model can then be written as:

$$F_{[i,j]} \sim \text{Bernoulli}(\text{Logistic}(\theta_{[i,j]})) \quad (1)$$

where:

$$\begin{aligned} \theta_{[i,j]} = & \alpha + \xi_{[i]} + \zeta_{[j]} + \delta_{[i,j]} + \\ & \beta_{[1,R(i),R(j)]} + \beta_{[2,S(i),S(j)]} + \beta_{[3,E(i),E(j)]} + \\ & \gamma_1 A_{[j]} + \gamma_2 P_{[j]} + \gamma_3 B_{[j]} + \gamma_4 U_{[j]} + \\ & \gamma_5 G_{[j]} + \gamma_6 Q_{[j]} + \gamma_7 W_{[j]} + \gamma_8 Z_{[j]} + \gamma_9 L_{[j]} + \\ & \gamma_{10} D_{[i,j]} + \gamma_{11} \bar{A}_{[i,j]} + \gamma_{12} \bar{P}_{[i,j]} + \gamma_{13} \bar{B}_{[i,j]} + \\ & \gamma_{14} \bar{U}_{[i,j]} + \gamma_{15} O_{[i,j]} + \gamma_{16} \bar{W}_{[i,j]} + \gamma_{17} K_{[i,j]} + \\ & \gamma_{18} M_{[i,j]} + \gamma_{19} \bar{Z}_{[i,j]} + \gamma_{20} \bar{L}_{[i,j]} \end{aligned} \quad (2)$$

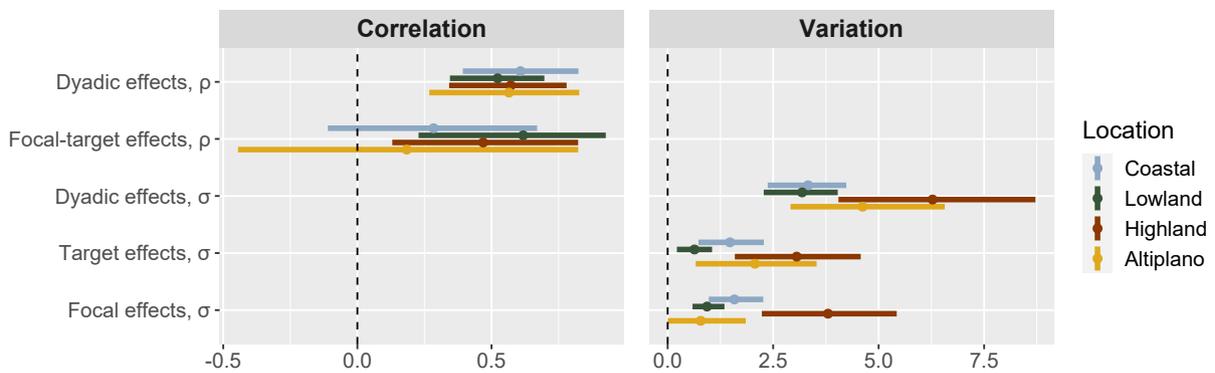


Figure 2: Random effects. The correlation parameter, ρ , for dyadic effects is indicative of the potential for friendship nominations to be reciprocal, after controlling for individual-level variation in the probability of sending and receiving ties. The correlation parameter, ρ , for focal–target effects is indicative of the strength of association between the individual-level likelihood of sending and receiving ties. The standard deviation parameters, σ , are indicative of the level of variation in focal/sender, target/receiver, and dyadic random effects. We find reliable evidence of dyadic reciprocity in friendship nominations across sites, indicating that even after accounting for the effects of a large suite of covariates, there is still dyadic structure in friendship nominations.

and where α is an intercept term, ξ are focal/giver random effects, ζ are alter/receiver random effects, δ are dyad random effects, β are a list of block random effects, and γ is a vector of standard slope coefficients. See Redhead et al. (2022) for additional details on the hierarchical pooling structure of the random effects.

The data and model code associated with the manuscript will be maintained at: www.github.com/danielRedhead/friendship-analysis. Analysis was conducted in R (R Core Team, 2017) using rstan (Stan Development Team, 2022) and the STRAND package for social network analysis (Redhead et al., 2022).

3. Results

3.1. Reciprocity in friendship nominations

As shown in Figure 2, and supporting Prediction 1 outlined in Table 1, we find reliable evidence of dyadic reciprocity in friendship nominations across sites, indicating that even after accounting for the effects of a large suite of covariates, there is still dyadic structure in friendship nominations. However, these estimates remain distant from both unity and zero, indicating that there is some degree of asymmetry in friendship nominations. Some nominations may be aspirational, and/or some individuals may simply have failed to recall an important fraction of their social ties.

3.2. Few effects of abilities or attributes on friendship nominations

Contrary to our expectations outlined in Predictions 2–3, we find that variables related to target ability/attributes generally have small or negligible effects on the probability of friendship ties across sites (Figure 3). However, one exception is attractiveness, which is positively associated with receiving friendship nominations in three of the four sites (Lowland, Highland, Altiplano). We also find positive effects of reproductive success in the two Afrocolombian

sites (Coastal, Lowland). The effect of education is surprisingly variable across sites: reliably negative in the Lowland site, but reliably positive in the Coastal one.

We find that behaviour in the RICH economic games (overall propensity scores for giving and leaving coins) is not reliably associated with friendship nominations (Figure 3). In other words, individuals who give more to others or leave more for others (on average) in experimental settings are no more or less likely to be nominated as friends.

At the Coastal site, we see positive effects of grip strength and RICH leaving propensity, but these effects are not replicated in any of the other sites.

3.3. Individuals preferentially form in-group ties compared to out-group ties

Across sites, we find some evidence in support of Prediction 4a, as there is a slight tendency for homophily on the basis of sex (Figure 4). This effect is most pronounced at the Highland site, but nearly absent at the Altiplano site. Notably, labor in the Coastal, Lowland, and Highland sites is structured appreciably by gender, with men generally focusing on fishing (Coastal) or agriculture (Lowland, Highland), and women generally focusing on tending to the home and caring for children. In the Altiplano site, however, individuals of either gender work primary in wage labor.

We also find a general tendency for homophily on the basis of ethnicity, lending support for Prediction 4a (Figure 5). For example, Afrocolombians are more likely to form friendships with other Afrocolombians than with members of other ethnic groups. There appears to be little ethnic structure in friendships at the Highland site, but this is only because there is actually little variation in ethnicity there, with most individuals being Mestizo. At the Altiplano site, recent Venezuelan immigrants are more likely to form ties with one another than they are with Colombians (as per Prediction 4b).

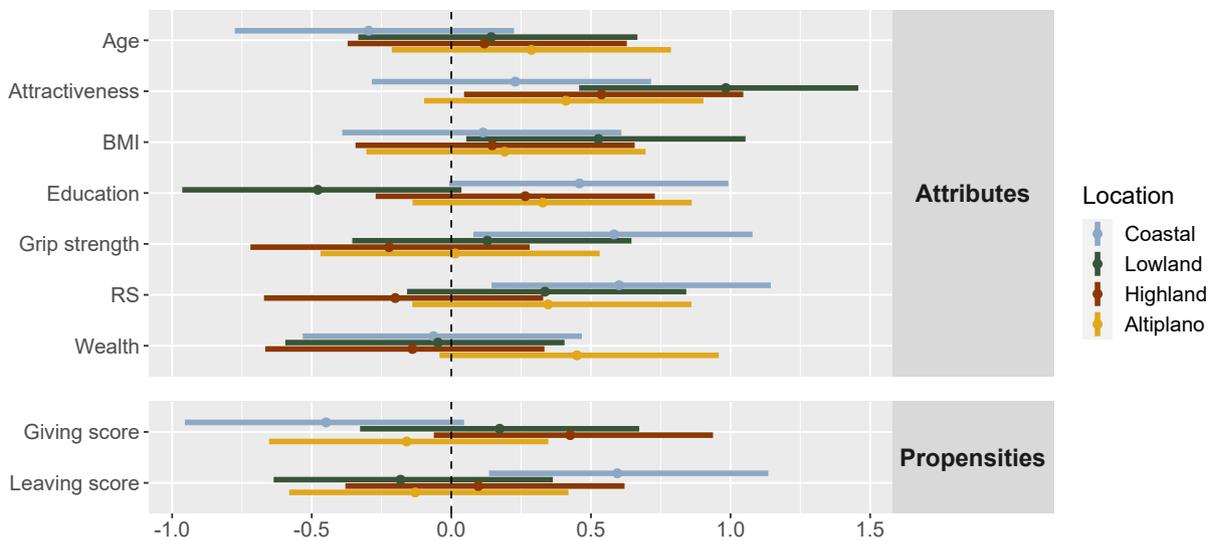


Figure 3: Standardized effects of individual-level (target/alter) covariates (as posterior means and 90 percent posterior credible intervals). Each bar represents a coefficient, and each color represents a site. For each covariate listed on the left-hand side of the figure, we plot four estimates, one for each site. Positive estimates indicate target/alter characteristics that are associated with an increased likelihood of being nominated as a friend. Estimates that do not overlap the vertical dashed line at zero are considered reliable.

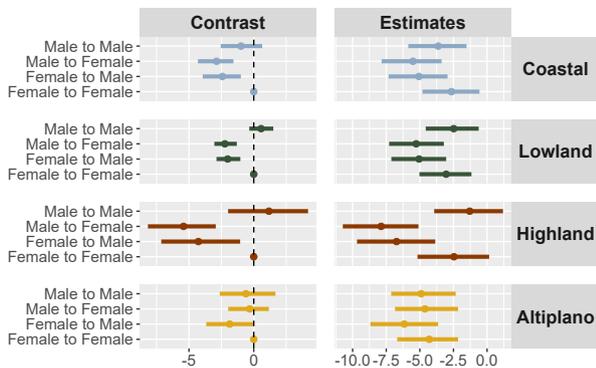


Figure 4: Block-level intercept offsets for interaction of focal and target sex (as posterior means and 90 percent posterior credible intervals). Each bar represents an intercept offset (right) or contrast (left), and each color represents a site. Estimates are indicative of offsets in log-odds of a tie from a global intercept term. Estimates that do not overlap one another can generally be considered reliably different, but contrasts need to be calculated to quantify differences. For example, at the Highland site, male-to-female friendship nominations are less likely than female-to-female friendship nominations (the base case of the contrast). On the other hand, at the Altiplano site male-to-female friendship nominations are not reliably less likely than female-to-female friendship nominations.

In general, there is little to any effect of religion on the structure of friendship ties. However, in both Lowland and Coastal sites, we find that Other-to-Other ties tend to be slightly larger than Catholic-to-Catholic ties, indicating that religion is more salient for individuals in smaller, tighter-knit religious communities (as per Prediction 4b). This effect,

however, is not replicated at the Highland and Altiplano sites.

3.4. Homophily on the basis of dyadic similarity is strong across many attributes

In contrast to the individual-level effects, there are fairly strong effects of dyadic variables on the probability of friendship ties (Figure 7). Across sites, there are negative effects of age distance, attractiveness distance, education distance, and spatial distance on the likelihood of a friendship tie. As outlined in Prediction 4c, friendships are thus more common among individuals who live in close proximity to each other, and those who are of similar age, attractiveness, and education level. Moreover, at the Coastal and Lowland sites, we find that individuals are also more likely to form friendships with alters who have similar levels of material wealth. Differences in BMI and political opinion, however, are not associated with lower probabilities of friendship.

3.5. There is appreciable overlap between friendship, food/money sharing, and kinship networks

We find considerable overlap between the probability of sharing ties and the probability of friendship in all four sites (Prediction 5). The association is the strongest in the two Afrocolombian sites (Coastal and Lowland), which have lower levels of material wealth compared to the other sites (Figure 7). We note that the same finding is seen in the experimental RICH allocation (i.e., giving) network as well (but is not seen in the RICH leaving network). The association between relatedness and friendship is positive in the Afrocolombian sites, and null in the Mestizo sites.

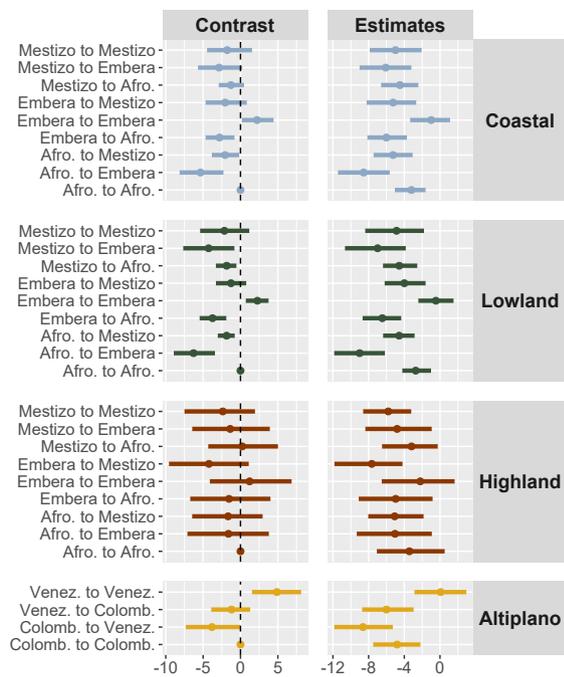


Figure 5: Block-level intercept offsets for interaction of focal and target ethnicity (as posterior means and 90 percent posterior credible intervals). Each bar represents an intercept offset (right) or contrast (left), and each color represents a site. Estimates are indicative of offsets in log-odds of a tie from a global intercept term. Estimates that do not overlap one another can generally be considered reliably different, but contrasts need to be calculated to quantify differences. For example, at the Altiplano site, Venezuelan-to-Venezuelan friendship nominations are more likely than Colombian-to-Colombian friendship nominations (the base case of the contrast). On the other hand, at the same site Venezuelan-to-Colombian friendship nominations are not reliably more likely than Colombian-to-Colombian friendship nominations.

4. Discussion

The current study contributes to the literature on friendship by analyzing how such social relationships are structured across four communities in rural Colombia. There is an increasing concern about replicability and generalizability in the social sciences (Camerer, Dreber, Forsell, Ho, Huber, Johannesson, Kirchler, Almenberg, Altmejd, Chan et al., 2016; Camerer, Dreber, Holzmeister, Ho, Huber, Johannesson, Kirchler, Nave, Nosek, Pfeiffer et al., 2018; Tiokhin, Hackman, Munira, Jesmin and Hruschka, 2019). As such, the present study makes use of novel data from ‘non-WEIRD’ populations, which tend to be underrepresented in empirical studies in the social sciences, and replicates research protocols across four different sites (Henrich, Heine and Norenzayan, 2010). We find that many, but not all, of our initial predictions were supported by the data. Many structural features of the observed friendship networks varied substantially between communities, but all networks were characterised by some degree of asymmetry in nomination. Many dyadic- and block-level predictors—i.e., ethnicity,

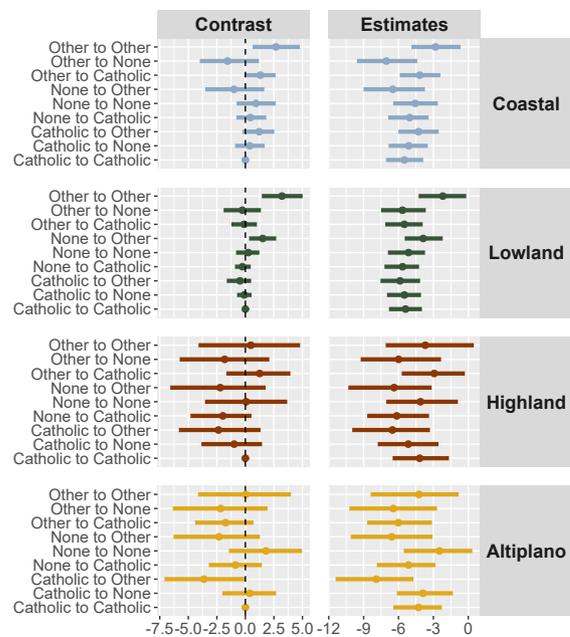


Figure 6: Block-level intercept offsets for interaction of focal and target religious identity (as posterior means and 90 percent posterior credible intervals). Religious identity as Catholic was coded as “Catholic”; other Christian denominations (e.g., individuals identifying as “Pentecostals” or “Christians”) were coded as “Other”. Individuals who were atheist, non-religious, or spiritual-but-not religious were coded as “None”. Each bar represents an intercept offset (right) or contrast (left), and each color represents a site. Estimates are indicative of offsets in log-odds of a tie from a global intercept term. Estimates that do not overlap one another can generally be considered reliably different, but contrasts need to be calculated to quantify differences. For example, at the Coastal site, Other-to-Other friendship nominations are reliably more likely than Catholic-to-Catholic friendship nominations (the base case of the contrast). Most other contrasts, however, do not suggest reliable differences in friendship likelihood as a function of religious identity.

age, attractiveness, education, spatial distance, sharing ties, and RICH giving ties—had reliable effects that generalized across field sites. However, several predictors—i.e., religion, BMI distance, political distance, wealth distance, and relatedness—were variable in their strength or direction across sites. Finally, we find little evidence of substantial associations between individual-level characteristics and the probability of friendship nominations, *after accounting for preferential assortment on the basis of the same variables*.

Existing research has advanced the idea that an individual’s ability and willingness to provide benefits to others should be one of the most important factors driving partner choice (Barclay, 2016; Redhead and Power, 2022). Hence, individuals high in culturally-valued attributes that signpost such an ability and willingness for benefit conferral are expected to be more desired as friends (i.e., in demand). However, as the distance between the levels of such attribute

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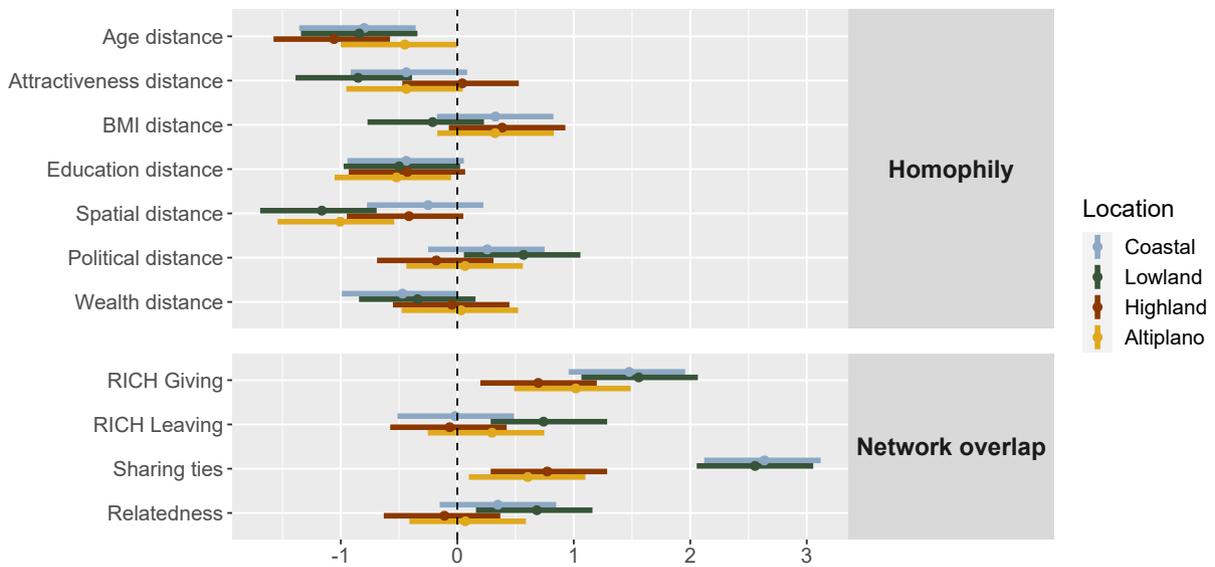


Figure 7: Standardized effects of dyad-level covariates (as posterior means and 90 percent posterior credible intervals). Each bar represents a coefficient, and each color represents a site. For each covariate listed on the left-hand side of the figure, we plot four estimates, one for each site. Positive estimates indicate dyadic characteristics that are associated with an increased likelihood of friendship nominations. Estimates that do not overlap the vertical dashed line at zero are considered reliable.

increases, the probability of a tie should decrease. Connections between individuals of vastly different attribute levels are less likely to be mutually perceived as beneficial (i.e., reflecting supply-side constraints; see Borgerhoff Mulder and Ross, 2019; Oh, Ross, Borgerhoff Mulder and Bowles, 2017, for a similar models of mating market dynamics). Therefore, individuals with high relative standing (e.g., in variables such as attractiveness and wealth) may be targets of friendships, reflecting aspirational biases (Ball and Newman, 2013). However, realised ties may in fact be less likely between individuals who are divergent on those same attributes (paralleling findings in mating markets; Prall and Scelza, 2022).

The present findings only partially support our predictions about the role of market-like dynamics in shaping friendship networks. Individuals with higher attractiveness ratings were more likely to receive friendship nominations, and ties were more likely to occur between individuals with similar attractiveness ratings across all sites. However, a slightly different pattern emerged in relation to material wealth. There was little evidence of wealthier individuals having more friends, and wealth homophily was only reliably observed in two of the four communities—the Afrocolombian-majority Coastal and Inland sites. This contextual wealth effect may likely reflect the higher levels of economic adversity faced by individuals in the Afrocolombian communities.

Across many settings, friendship entails an expectation of economic support (Hruschka, 2010). Here, this is highlighted by the strong overlap between food/money transfer and friendship networks, especially in the two Afrocolombian communities. Hence, wealthy individuals living in communities characterised by more adverse economic

conditions may be more likely to form friendships with similarly wealthy others in order to minimise the costs of resource outflows arising from asymmetrical transfer ties. It is important to note, however, that the limited sample size of communities appearing in the present study ($n_{communities} = 4$) constrains the generalisability of our conclusions. Future research, based on data from a larger number of communities in different cultural and ecological settings (e.g., Koster et al., 2017), is necessary to evaluate the relevance of wealth-based market-like dynamics in partner choice.

Patterns of homophily may also emerge through other forms of preferential assortment, which may be expected to decrease problems associated with miscoordination and miscommunication (McElreath et al., 2003). The present study provides evidence of such tendencies on the basis of several attributes—e.g., age, attractiveness, and education—that have been repeatedly documented in the extant literature (McPherson et al., 2001). However, an unexpected finding of the current study was that individuals did not assort on the basis of similarity in political belief. Individuals in these rural communities do not appear to consider political differences to be an important dimension on which friendship decisions should be based. This finding stands in contrast to what has been observed in many Western and industrialised settings, where convergent political opinions seem to be important for creating and maintaining both social and romantic relationships (e.g., Huber and Malhotra, 2017; Oosterhoff, Poppler and Palmer).

Finally, the present study indicates that there is important variation in how different networks overlap across settings. Previous research has emphasised how many positive social relationships, and different forms of social and material support generally overlap (Diviák, Dijkstra and Snijders, 2019;

Ferriani, Fonti and Corrado, 2013; Redhead and von Rueden, 2021). Here, we found substantial and reliable positive associations between friendship and food/money transfers in all communities. That is, individuals in all communities were more likely to share food or money with their friends (or vice-versa). The Afrocolombian-majority communities in the current study exhibit a much greater network overlap compared to the Mestizo-majority communities. Akin to the dynamics underlying wealth homophily, the variation in network overlap observed between communities is likely related to the different economic conditions that individuals face. As the average level of wealth within a community increases, the demand for food or money transfers on the basis of need may likely decrease. In turn, the nexus between resource transfers and friendship may weaken, such that expectations of material support between friends may be considerably lower in wealthier communities.

4.1. Conclusions

Friendships have been widely observed across human societies. Past research has indicated that there are a core set of features—such as social support and positive affect—that underpin friendship across many cultures, while a multitude of other factors appear to be more variable across cultural and ecological settings (Hruschka, 2010). Here, the current study has provided much-needed empirical insight into the different processes and individual-level characteristics that shape friendship networks in four culturally, economically, and demographically diverse populations in rural Colombia. Overall, the present findings have highlighted the importance of shared, or similar, attributes (i.e., homophily) to the structure of friendship networks. The effects of some attributes, however, differed considerably across communities, which raises questions as to the cultural, demographic, and economic factors that may drive such variation.

CRedit authorship contribution statement

Daniel Redhead: Conceived of study, reviewed the literature, developed models, wrote the paper. **Augusto Dalla Ragione:** Conceived of study, reviewed the literature, developed models, wrote the paper. **Cody T. Ross:** Collected data, developed models, wrote the paper.

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