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Antti O. Tanskanen
Mirrka Danielsbacka
Anna Rotkirch

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Relationship quality among younger and middle-aged siblings: the role of childhood family arrangements

Antti O. Tanskanen^{1 2}, Mirikka Danielsbacka^{1 2} & Anna Rotkirch²

¹ University of Turku, Finland

² Population Research Institute, Väestöliitto, Finland

Abstract: Sibling relationships are the social bonds with longest duration across the life course. Using a large and population-based data of younger and middle-aged Finns, we test how childhood co-residence duration and maternal perinatal association (MPA) correlate with contact frequency, emotional closeness and provision of help between adult siblings. Employing sibling fixed-effect models we find that duration of co-residence in childhood and MPA are indeed associated with increased relationship quality in all three measures. Provided MPA, sibling relationship quality is high independent of co-residence length, but in the absence of MPA, increased co-residence duration is associated with better relationship quality. Co-residence duration is more strongly associated with provision of help in same-gender than opposite-gender sibling dyads. Full siblings report better relationship quality than half siblings do, although the co-residence duration mediates the effect of genetic relatedness in emotional closeness between full and maternal half siblings and in provision of help between full and paternal half siblings. Moreover, MPA serves as a mediator in the case of contact frequency and emotional closeness between full and maternal half siblings. These findings are discussed with reference to key theories of kin detection.

Keywords: Contact frequency, co-residence duration, emotional closeness, helping, kin detection, maternal perinatal association, siblings

Introduction

Genetic relatedness regulates several aspects of social behavior. Across societies individuals are more likely to invest time, help, and other resources towards close kin than distant kin or non-kin (Abbot et al. 2011) and appear to have evolved dispositions to avoid mating with close relatives (Antfolk and Wolf 2016). In order to regulate social behaviour according to the degree of genetic relatedness, individuals need, however, first to recognize to whom they are related. Since it is impossible to directly observe genetic relatedness, humans rely on various cues, which help to determine whether a person is a relative or not. Such cues need not always reflect actual genetic relatedness, but should have done so sufficiently in ancestral environments to be favoured by natural selection. Kin detection cues can be either direct (between the individuals concerned) or indirect (deduced from third parties or the environment). Direct kin detection cues may include, for instance, facial resemblance (e.g. Bressan and Zucchi 2009), smell (Brown and Eklund 1994), or personality similarity (Krupp et al. 2011). However, for the most part, humans have to rely on indirect kin detection cues available in our social environment. One indirect cue is linguistic assignment: all languages have some terminology to denote immediate family members and more distant kin, and kin terminology is also appropriated to signal close social bonds and solidarity between two unrelated individuals or in social groups (Rotkirch 2019). Another and sociologically highly relevant indirect cue for kinship is social association and physical proximity.

Sociologist and anthropologist Edward Westermarck (1901) was the first to suggest that co-residence in childhood serves as a cue for kin detection. In his book *History of Human Marriage*, Westermarck discussed the avoidance of incest in couple relations and the roots of incest aversion. “All (previous scholars) assume that men avoid incestuous marriages only because they are taught to do so. But... (t)he home is kept pure from incestuous defilement neither by laws, nor by customs,

nor by education, but by an instinct which under normal circumstances makes sexual love between the nearest kin a psychological impossibility” (ibid., 319), Westermarck wrote, and suggested that the “instinctive aversion to marriage between persons living closely together” (ibid., 334) had evolved in humans and other species in order to avoid inbreeding.

The so-called “Westermarck hypothesis” states that physical proximity in early childhood between adults and a child, and between children, provides an important cue for genetical kinship and thus should regulate individuals’ behavior in later life. Prior studies have provided evidence for the Westermarck hypothesis in relation to his original topic, marriage and sexual aversion (e.g., Wolf 1993; Rantala and Marcinkowska 2011; Walter and Buyske 2003; see Shmor and Simchai 2009; Maryanski, Sanderson, and Russell 2012 for recent turns in the prolonged debate on incest aversion in anthropology). However, the thesis can also be extended to include social bonding between household members. The “extended Westermarck hypothesis” predicts that physical proximity in early childhood fosters not only incest aversion but also attachment, altruism and relationship quality.

Debra Lieberman and colleagues (2007) extended Westermarck’s original hypothesis also methodologically to include another possible kin detection cue, namely maternal perinatal association (MPA; or seeing one’s own mother nurse a newborn baby), a measure quickly adopted by others (e.g., de Smet et al. 2014). Among our ancestors, a woman who took care of and breast-fed a newborn baby was most likely the biological mother of this infant, meaning that the MPA strongly correlated with assumed genetic relatedness. Because MPA provides a reliable cue to detect a mother and offspring, individuals can use it also as a cue for sibling detection; if my mother takes care of a newborn child, this child most likely is my sibling.

Although MPA often correlates with co-residence, this is not always the case. Today's family arrangements are increasingly diversified compared to mid-20th century families (Thomson 2014). A similar if not larger variation in family arrangements was likely also in ancestral hunter-gathering societies, as indicated by studies of contemporary hunter-gatherers (Johns et al. 2017; Bentley and Mace 2012). Hence in some situations, MPA may provide a complementary cue to siblings living apart, due to for instance age differences, having different custodian parents, or being half siblings. Obviously, MPA can only be detected by older siblings because younger siblings are not present during the perinatal period of their older siblings. Younger siblings can only use the second most informative social kin detection cue, childhood co-residence duration, which taps into both the time spent with siblings and the period children tend to receive most child care and other forms of parental investment (Lieberman and Billingsley, 2016; see Trivers 1972; 1974 on parental investment).

Previous studies of the Westermarck hypothesis have mostly explored sexual aversion and inbreeding avoidance: research considering the effects of childhood co-residence on sibling altruism, sibling directed kin investments and relationship quality, have been scarce and we know of no other prior study using large and population-based data. Here, we test the extended Westermarck hypothesis with relation to relationship quality among adult siblings. The hypothesis is tested through two social cues, namely childhood co-residence duration and MPA, arguably two of the most important indirect kin detection mechanisms among close family members (Lieberman et al. 2007). Sibling relationship quality is indicated here by three factors measuring the quality of social ties: contact frequency, emotional closeness, and kin support.

Our investigation makes several important contributions to the existing literature. Some prior studies have shown support for the impact of co-residence duration and MPA as cues to siblingship,

however, they have detected the effect mainly in the context of sexual disgust and incest aversion, rather than kin investment and quality of social ties. The rare existing studies concerning the sibling relationship quality have been based on small-scale and non-representative samples of college students (Lieberman et al. 2007; Sznycer et al. 2016), meaning that the findings may not be considered very robust (see Henrich et al. 2010 for discussion). In the present study, we conduct the analyses using population-based data gathered from Finland (coincidentally, the country where Westermarck grew up and where he retired in old age). Methodologically, we utilize sibling fixed-effect regressions, which concentrate on the effects within families and take into account unobserved factors shared by siblings, making the findings more robust compared to ordinary regressions (Carlin et al. 2005).

Theory and hypotheses

Ultimate reasons and proximate mechanisms

Scientific explanations are often been divided into two groups, namely those providing ultimate reasons and those focusing on proximate mechanisms (Nielsen 1994; Scott-Phillips et al. 2011). Questions related to ultimate reasons consider the possible evolutionary function of a behavior and ask why natural selection might have favored a certain trait. With regard to sibling ties, ultimate questions consider, for instance, why closely related siblings tend to help each other more and are emotionally closer to one another than distantly related or non-related siblings. Proximate explanations, in turn, describe the mechanisms that trigger and enable the behavior. Proximate research questions may consider, for instance, how different social and environmental factors (e.g., residential proximity or familial living arrangements) facilitate helping behavior and emotional closeness among siblings (e.g. Volkom 2006). Traditionally, there has been a clear division of labor

between disciplines, so that evolutionary researchers have focused more on the ultimate questions, whereas a wide range of sociologists have adopted the view that sociology should concentrate on middle-range theories and discover proximate mechanisms (e.g., Hopcroft 2016; Sanderson 2012).

Although scholars typically concentrate on either ultimate or proximate reasons, with those who take both into account being a minority, it is important to note that ultimate and proximate theories are complimentary rather than mutually exclusive. One of the strongest features of the original Westermarck hypothesis is that it included both ultimate evolutionary explanations (inbreeding avoidance) and a proximate-level mechanism (childhood co-residence).

Two major ultimate evolutionary reasons relevant for our study question are inclusive fitness and inbreeding avoidance. Inclusive fitness is a hypothesis stipulating that altruistic behavior (behavior with a cost to the individual and a benefit to the receiver) between individuals should be stronger with higher genetic relatedness (Hamilton 1964). The hypothesis builds on the observation that in terms of reproductive success or fitness (i.e., the transmission of genes to future generations), it can be beneficial to invest time and resources in close relatives even if the costs are relatively high, while investing in more distant relatives or non-relatives with high costs is less beneficial (Trivers 1971). By investing in genetically related kin, and especially in younger kin, it is possible for an individual increase the likelihood of gene transmission to future generations (Hughes 1988). Hence nepotistic efforts may spread in populations, leading individuals to behave in ways that take into account degrees of genetic relatedness. An increasing number of empirical studies of both humans and non-human animals have provided support for higher altruistic helping with closer genetical relatedness, showing that more closely related individuals invest more material and non-material support in one another (see Abbot et al. 2011; Salmon and Shackelford 2011; Tanskanen and Danielsbacka 2019 for reviews).

A second evolved behavioural trait with relevance for kin detection is inbreeding avoidance. Inbreeding depression – that is, the decreased survival and fertility rates of individuals whose mother and father are genetically related to each other – is well documented in many species (Charlesworth and Willis 2009). Because inbreeding can have harmful consequences for the two most important fitness indicators, survival and fertility, natural selection can be expected to have favoured psychological cues which help individuals avoid mating with close relatives. As noted above, Westermarck (1901) argued that co-residence during childhood is the proximate mechanism activating inbreeding aversion. The most prominent evidence for the Westermarck hypothesis comes from anthropological research about sexual avoidance among genetically unrelated individuals who have been raised in “sibling-like” conditions. When unrelated children have grown up together in peer groups, childhood attachment often leads to sexual avoidance and disgust in later life (e.g., Lieberman 2009; Lieberman and Lobel 2012; Talmon 1964; Wolf 1995; Maryanski et al. 2012). Other evidence comes from likelihood of occurrence of incest between family members (Pullmann 2018).

Childhood family constellation and sibling ties in adulthood

Childhood proximity can be an important driver of sibling-directed altruism. Lieberman and colleagues (2007) were the first to investigate how both childhood co-residence duration and MPA are associated with sibling relationship quality, using two outcome variables. First, they considered whether individuals are motivated to help their siblings in a life-threatening situation by asking how willing a participant was to donate a kidney if their sibling needed one. Second, they enquired about kin support by asking how many favors a participant had provided to their sibling during the last month. Using a sample of US college students, the authors detected that both childhood co-

residence duration and MPA were associated with increased investments in siblings. In addition, the MPA was a stronger predictor of sibling-directed investment than childhood co-residence duration; when the MPA cue was present (i.e., in older siblings), co-residence duration was not associated with investment in siblings. However, when the MPA cue was absent (i.e., typically in younger siblings), childhood co-residence duration was a strong predictor of kin investment. Similar findings were detected also in a replication study, which used data of college students from six populations (Sznycer et al. 2016).

Both gender and genetic relatedness are known to shape sibling ties (Lieberman et al. 2003; Sznycer et al. 2016). One development of the Westermarck incest aversion hypothesis predicted that since most individuals are heterosexual, incest aversion should be stronger between opposite-gender siblings. Empirical evidence indicated that, as expected, self-reported childhood co-residence and MPA strongly predicted sexual avoidance in opposite-gender siblings (e.g., Antfolk et al. 2012; Antfolk and Wolf 2016; Bevc and Silverman 2000; Fessler and Navarrete 2004; Lieberman et al. 2007). In this article, we extend this prediction to sibling altruism and relationship quality: as a consequence of higher incest aversion, co-residence and MPA can also be expected to make opposite-gender siblings more distant from one another compared to same-gender siblings.

Regarding genetic relatedness, inclusive fitness theory predicts notable differences in relationship quality between full and half siblings (Hamilton 1964). Full siblings share the same mother and father, while maternal half siblings share the same mother only and paternal half siblings share the same father only. Individuals share on average 50% of their genes with their full siblings and 25% of their genes with half siblings. Consequently, inclusive fitness theory predicts that individuals have the tendency to invest more time and other resources in full than half siblings, a prediction that

has received clear support from several studies from present-day Western societies (e.g., Pollet and Hoben 2011; Steinbach and Hank 2018; Tanskanen and Danielsbacka 2018).

Studies also show that gender and genetic relatedness interact with regards to sibling altruism. Full siblings invest more in one another than maternal half siblings and maternal half sibling more than paternal half siblings (e.g., Pollet 2007; Tanskanen and Danielsbacka, 2014), however, such studies have rarely concerned length of childhood co-residence duration and MPA (but see Sznycer et al. 2016). Here we argue that the difference in relationship quality between full, maternal and paternal half siblings could be related to childhood co-residence duration and MPA, because in contemporary Western societies children typically stay with their mothers, or spend most of their time with their mother, if their parents separate. This means that full and maternal half siblings are more likely to grow up together in the same household and among them the MPA cue can be present, while paternal half siblings have rarely spent their whole childhood together and among them the MPA cue is absent. Based on this argument we predict that co-residence duration and MPA, not only the actual (or alleged) genetic relatedness between siblings, shape sibling relationship quality. This means that full and half siblings should be equally or almost as close to one another if they have lived their childhood together in the same household or if the MPA cue is present. Of course, other biological cues of higher genetic relatedness such as physical appearance may still serve to render full siblings closer than half siblings.

The present study considers several predictions derived from the theories of kinship and sibling relations discussed above, predicting that childhood co-residence duration and MPA regulate adult sibling ties. The following hypotheses are tested in this study:

Hypothesis 1: The extended Westermarck hypothesis predicts that longer duration of childhood co-residence and the presence of MPA are both associated with better relationship quality in adult siblings.

Hypothesis 2: The effect of childhood co-residence is expected to be moderated by MPA. If the MPA cue is absent, co-residence duration is a stronger predictor of sibling relationship quality than when the MPA is present.

Hypothesis 3: The strength of the extended Westermarck hypothesis is expected to vary with gender. When the childhood co-residence duration increases, the relationship quality in same-gender sibling dyads (in two sisters or two brothers) improves compared to opposite-gender dyads and when the MPA cue is present, the relationship quality in same-gender sibling dyads improves compared to opposite-gender dyads.

Hypothesis 4: Relationship quality is expected to be lower between half than full siblings; however, if the MPA and co-residence duration serve cues for genetic relatedness, they should also mediate this association. Hence, it is expected that relationship quality between full and half siblings to be similar when co-residence duration between these two groups match, and relationship quality between full and maternal half siblings to be similar when the MPA cue is present in both groups.

Data, measures and methods

Data

We use population-based survey data from the Generational Transmissions in Finland (Gentrans) project. The Gentrans gathers information on two family generations: the Finnish baby boomer generation born between 1945 and 1950 and their adult children born between 1964 and 1999. Here, we used only the survey of the younger generation because it included systematic information on participants' household structure and family arrangements during childhood. This nationally representative survey was conducted by Statistics Finland in autumn 2018 and included 1,945 younger and middle-aged adults who were between 19 and 56 (Mean = 42, SD = 6.09).

The present study sample was constructed in several steps. First, we included participants who had living siblings and available data concerning all variables studied here, leaving us with a final sample of 1,427 adults. Next, the data was reshaped into a long format, so that observations were recorded from the perspective of the original respondent's siblings. This resulted in a total of 2,639 observations from 1,427 unique individuals in the data (approximately 1.9 siblings per respondent). Our sibling fixed-effect models include only participants with two or more siblings because they compared sibling relationship quality among original siblings from same family (i.e., among siblings who shared the same mother and/or father); the fixed-effect sample had 1,947 observations from 762 unique individuals.

Measures

Sibling relationship quality variables. The dependent variables measure contact frequencies, emotional support, and provision of help, which have often been used as indicators for sibling relationship quality (Tanskanen and Danielsbacka 2020). In the Gentrans survey, contact frequency was measured by asking participants in a single question to report using a 5-point scale (ranging from 0 = never to 4 = several times a week) how often they have had contact with their siblings in

the last 12 months either in person, by phone, or via the Internet. Emotional closeness was indicated by asking how emotionally close respondents consider their siblings using a 5-point scale (ranging from 0 = very distant to 4 = very close). Finally, it was asked in the questionnaires whether respondents have provided practical or financial help to their siblings in the last 12 months (0 = no, 1 = yes). Contact frequency, emotional closeness and help variables were gathered separately for four of the respondents' oldest siblings. Bivariate correlations of the three sibling relationship quality measures show that the strongest correlation exists between contact frequency and emotional closeness ($r = 0.62$). Moderate correlations exist also between contact frequency and help ($r = 0.41$) as well as emotional closeness and help ($r = 0.33$) (all these correlations are statistically significant: $p < 0.001$).

Childhood family arrangement variables. The main independent variables are childhood co-residence duration with siblings and the maternal perinatal association (MPA). The information about childhood co-residence duration and MPA were again gathered separately for four of the respondents' oldest siblings. Childhood co-residence duration was indicated by asking the respondents to report how long they had lived with their sibling before their 18th birthday via a 5-point scale (0 = no time at all, 1 = only for a short time, 2 = less than half of the time, 3 = more than half of the time, and 4 = the entire time). In the analyses, the group that indicated "no time at all" was used as a reference category. MPA was measured through asking whether the participants had lived in the same household with a sibling immediately after the respondent was born (if the respondent was a younger sibling) or immediately after the sibling was born (if the respondent was an older sibling). MPA was coded as 1 (i.e., MPA is present) when the participant started co-residence with his or her sibling at the sibling's birth and the participant shared their mother with the sibling, and MPA was coded as 0 (i.e., MPA is absent) in any other circumstance. There was a moderate correlation between childhood co-residence duration and MPA ($r = 0.49$, $p < 0.001$).

Covariates. To provide more robust results we controlled for several factors that have been shown to correlate with sibling relationship quality in prior studies (e.g., Pollet and Hoben 2011; Tanskanen and Danielsbacka 2020). These include gender constellation of sibling pairs, age difference between siblings, parenthood status of sibling pairs, genetic relatedness (full siblings, maternal or paternal half siblings; adoptive and step-siblings are dropped from the data because only 1% of respondents reported that they share neither the same biological mother nor father with siblings), siblings' financial condition, and geographical distance between siblings. In random-effect models, respondents' gender, marital status (single, cohabiting, married, widowed), birth year, number of siblings, education, and birth order were also controlled for. In sibling fixed-effect models all background characteristics related to respondents (e.g., age, education, and number of siblings) and shared by siblings (e.g., mothers' and/or fathers' age, education, and social values) are taken into account due to the design itself, whether this information exists in the data or not. Descriptive statistics are available in Table 1.

< Table 1 somewhere here >

Methods

We analyze the Gentrans data using multilevel linear regression analysis and employ both random and sibling fixed-effect regressions. In the case of the dichotomous help variable, we did not use logit models because of their limitations (Mood 2010). However, we executed sensitivity analyses using logistic regression models with similar results (not shown) and thus we can consider the loss of information as minor. Sibling fixed-effect regressions were used because they can provide more robust results regarding the association between childhood family arrangements and relationship

quality in adulthood compared to random-effect models. In general, sibling fixed-effect regressions are used to investigate effects among participants with two or more siblings by comparing the relationship quality in siblings from same families. Sibling fixed-effect models are designed to reduce omitted variable bias, and control for any observed or unobserved confounding factors shared by siblings (Carlin et al. 2005). Since the sibling fixed-effect procedure removes problems related to unobserved heterogeneity at the family level, they may also provide more causal estimates compared to random-effect models.

Although sibling fixed-effect models have several strengths, they are not without limitations. One limitation is that these models cannot account for unobserved characteristics not shared by siblings. Fixed-effect models may also be exacerbated by reduced sample size because there may be a small number of participants who have variance in both the outcome measure and main independent factors. Despite these limitations, sibling fixed-effect models can be considered to provide a sophisticated method to study the associations between childhood family arrangements and adult sibling relationship quality and is well-suited to study family complexities (Kalmijn et al. 2019). To help to interpret the findings we calculated predictive margins from the regression models (see Williams 2012 for margins command in Stata).

Results

Below, we explore our four hypotheses. First, we study associations between childhood co-residence length and MPA on sibling relationship quality in adulthood (Hypothesis 1), and also investigate whether the length of childhood co-residence is a stronger predictor of sibling relationship quality when the MPA is absent rather than present (Hypothesis 2). We then assess whether childhood co-residence duration shapes sibling relationships differently in opposite-gender

than in same-gender sibling pairs, and the role of MPA in different gender dyads (Hypothesis 3). Finally, we investigate whether the co-residence duration and MPA mediates the relationship quality between full and half siblings (Hypothesis 4). The effect of genetic relatedness is studied between full and half siblings only due to the low numbers of adoptive and step-siblings in the data (only 1% of respondents reported that they share neither the same biological mother nor father with siblings). Also when we investigate the potential mediating effect of MPA, only full and maternal half siblings will be considered because the MPA cue is absent in paternal half siblings (who have different mothers).

We now proceed to the results from the multilevel models, which are reported for total regression and sibling fixed-effect regression models side-by-side. We investigated first whether increased length of childhood co-residence and the presence of MPA are associated with better relationship quality in siblings (Hypothesis 1). As Table 2 indicates, sibling relationship quality as measured by contact frequency, emotional closeness, and help between siblings all increase with longer childhood co-residence. Table 2 also shows that when the MPA cue is present, sibling relationship quality is better than when it is absent, indicating that both cues partly complement each other. These findings were similar in both the total and sibling fixed-effect models.

< Table 2 somewhere here >

Next, we investigated whether the length of childhood co-residence was a stronger predictor of sibling relationship quality in the presence of the MPA cue (Hypothesis 2). To study this question, we include the interaction term between childhood co-residence and MPA in the models (Table 3). Provided maternal perinatal association, childhood co-residence length is a weaker predictor of kin contact, closeness, and help, compared to the absence of the MPA cue. These findings are

illustrated in Figures 1, 2, and 3. The point where the lines of co-residence duration and MPA cross is “entire time,” meaning that the presence of the MPA cue corresponds to 18 years of co-residence during childhood. The effect was similar in the case of all three measures of sibling relationship quality analyzed here. Finally, we included co-residence duration and MPA in the same model, meaning that for co-residence duration the effect of MPA was statistically removed, and for MPA the effect of co-residence duration was removed. Also when these variables are mutually adjusted, both co-residence duration and the MPA correlate with sibling relationship quality (Appendix Table 1), supporting our first hypothesis.

< Table 3 somewhere here >

< Figure 1 somewhere here >

< Figure 2 somewhere here >

< Figure 3 somewhere here >

Hypothesis 3 predicted, based on gender constellations in sibling dyads, that childhood co-residence duration and MPA would be associated with increased sibling relationship quality more strongly in same-gender than opposite-gender dyads. We investigated this by including the interaction term between the length of childhood co-residence and gender constellation in the models (Table 3). Results show that in female-male sibling dyads, provision of help increased with increased co-residence duration, while no similar effect was detected for female-female or male-male sibling dyads (Figure 4). However, no statistically significant associations were found for contact frequency and emotional closeness. We also investigated the interaction between MPA and gender

constellation, finding no significant interaction effects in the case of any of the three measures of sibling relationship quality. To separate possible differences between male-male and female-female siblings dyads, we also ran the models separately for men and women (not shown). Among brothers (but not among sisters or brother-sister dyads), longer co-residence duration in childhood was associated with higher emotional closeness in adulthood. Hence, the second hypothesis was only partly supported.

Hypothesis 4 assessed the relationship quality between full and half siblings. In Table 4, the first models consistently show an association between genetic relatedness and sibling relationship quality when all other covariates, with the exception of the co-residence duration or MPA, are controlled for. The second models control for the co-residence length or MPA in addition to other variables. When co-residence duration is not controlled for, full siblings reported more contact and emotional closeness than maternal or paternal half siblings and full siblings provided more help compared to paternal half siblings, as can be expected. However, once co-residence duration is taken into account, the difference in emotional closeness between full and maternal half siblings, as well as the statistically significant differences in provision of help between full and paternal half siblings disappear. This indicated, in support of the hypothesis, that the co-residence duration mediates the effect of genetic relatedness. A Sobel z-test for mediation indicated that co-residence duration is indeed a mediator in the case of both these variables ($p < .05$). In addition, once MPA is controlled for, the difference in contact frequency and emotional closeness between full and maternal half siblings disappeared, and based on the Sobel z-test, MPA is a mediator in both cases ($p < .05$).

< Table 4 somewhere here >

We end the Results section with a brief discussion of the associations between covariates and sibling relationship quality in cases where co-residence duration or MPA were not controlled for (Appendix Table 2). Female-female sibling pairs had more contact and emotional closeness than male-male or mixed dyads. Moreover, male-male dyads reported more help and mixed dyads less help than female-female dyads. According to parenthood status, siblings who were both childless adults provided more help compared to siblings who both had children. Full siblings reported more contact and emotional closeness compared to maternal and paternal half siblings, and full siblings also provided more practical help than paternal half siblings. Respondents were emotionally closer with their financially better-off siblings, and contact frequency and provision of help decreased with greater geographical distance.

Discussion

The present study considered how childhood family constellation shapes sibling relationship quality in adulthood. We investigated the role of the two most important indirect environmental kin detection cues for siblings, namely childhood co-residence duration and maternal perinatal association (MPA). In line with predictions derived from kinship theories, our data from contemporary adult Finns showed that length of childhood co-residence and MPA shaped relationship quality for adult siblings. Siblings who had lived a longer period with one another in the same household during childhood also reported better relationship quality with each other when they reached adulthood. Moreover, individuals who had seen their mother nursing a younger sibling during the infant's perinatal period (i.e., the MPA cue was present) had stronger sibling ties in adulthood compared to those who had not (i.e., the MPA cue was absent). Hence, our findings provide robust evidence for the long-term effects of childhood family constellation on sibling ties in later life.

Moreover, we found that the co-residence cue was a stronger predictor of sibling relationship quality when the MPA cue was absent rather than present. This was the case in all sibling relationship quality indicators analyzed here: contact frequency, emotional closeness, and provision of help. Interestingly, the presence of the MPA cue corresponded to full childhood co-residence in the same household with siblings (i.e., 18 years). This finding is in line with the study by Lieberman and colleagues (2007), which found that for sibling-directed altruism, as indicated by favours provided to siblings and willingness to make costly sacrifices for them, the presence of MPA cue coincides with 18 years of co-residence. The same authors also argued that when co-residence length and MPA cues are both available, individuals should use the MPA which is a more reliable cue for kinship. In line with this hypothesis, they detected that when co-residence duration and MPA were mutually adjusted in the same model, the effect of co-residence duration disappeared, while MPA remained a predictor of sibling directed altruism. However, contrary to this prior finding, we found that when co-residence duration and MPA were included simultaneously in the same model, they were both significant predictors of sibling relationship quality. This indicates that both childhood co-residence length and MPA may be equally important kin detection cues in human siblings.

Key theories of kin detection have claimed that the presence of cues for kinship should similarly affect both incest aversion and nepotistic efforts (Billingsley et al. 2018; Lieberman and Billingsley 2016). A central prediction is that, because most people are heterosexual, kin detection cues should regulate the relationship quality more strongly between opposite-gender siblings. Consequently, the extended Westermarck hypothesis could predict that relationship quality is affected differently among same-gender and different-gender siblings. We were unable to find convincing support for this hypothesis. The only exception was the finding that co-residence duration was more strongly

associated with provision. The only exception was the finding that co-residence duration was more strongly associated with provision of help in same-gender sibling dyads than opposite-gender dyads. The lack of gender-based differences could be because of the fact that, from the gender perspective, sibling relationship quality substantially differs from incest aversion. From an inclusive fitness perspective, emphasizing the evolutionary benefits of nepotistic altruism, sibling contact, closeness, and support should not be as dependent on gender similarity as incest aversion, because investing time and support in closely related kin should pay off in terms of increased fitness in both same-gender and opposite-gender sibling dyads. Furthermore, gender-role stereotypes and skills in division of work is also likely to affect behavior, for instance so that practical help is more often solicited by sisters from brothers and childcare help by brothers from sisters.

Prior studies have indicated that genetic relatedness shapes adult sibling ties and render full siblings closer compared to half siblings (e.g., Pollet 2007; Steinbach and Hank 2018; Tanskanen and Danielsbacka 2014). Crucially, however, humans build their understanding of genetic relatedness not on abstract notions of genes, but on observations of their family surroundings. We showed that co-residence duration and MPA mediated the effect of genetic relatedness. Co-residence duration mediates the effect of genetic relatedness in emotional closeness between full and maternal half siblings and provision of help between full and paternal half siblings. MPA mediates the effect of genetic relatedness in the case of contact frequency and emotional closeness between full and maternal half siblings. Hence, when full and half siblings have similar kin detection cues available, the relationship quality between these groups becomes more similar. This finding questions several earlier assertions about genetic relatedness, showing that environmental cues are the most important at least for certain outcomes, but also shows an elegant way to integrate evolutionary and sociological, and ultimate and proximate, explanations.

To best of our knowledge the present study is the first that has investigated how childhood co-residence duration and MPA are associated with adult sibling relationship quality with large-scale and population-based data. Compared to prior studies on the topic, we have been able to study more reliably not only the direct effects of childhood co-residence duration and MPA on sibling relationship quality but also interaction effects of gender and genetic relatedness. We measured sibling relationship quality with three different outcomes (contact frequency, emotional closeness, and provision of help), and in most cases all three variables led to similar conclusions, underscoring the strength of the findings. Methodologically, we have used sibling fixed-effect models where all factors shared by siblings are taken into account. Our data also allowed us to control for several factors not shared by siblings and potentially shaping sibling relationship quality. All these abovementioned factors increase the robustness of the findings presented in this study.

A limitation of the present investigation is the fact that although sibling fixed-effect regressions in theory control for all characteristics shared by siblings, there are aspects of family life that siblings may experience differently and could be not controlled for. There could also be factors influencing sibling ties that are not shared by siblings, which are not available in the data and thus cannot be taken into account. Obviously, all such factors are difficult if not impossible to control for. Finally, correlational results should be always approached with caution. For instance, it is possible that rather than co-residence duration and MPA, some other factors that highly correlate with them are responsible for the results. However, it is not clear what these factors could be, and to date these potential confounding factors have not been identified.

The present study has considered long-term effects of childhood family arrangements on sibling relationship quality in adulthood. The study has shown that indirect kin detection cues that are available in one's social environment during early life can be important factors shaping social ties

over the life course. Our findings contribute to the increasing body of research showing that evolutionarily rooted factors may be responsible for substantially shaping the social behavior of humans not only in our ancestral past but also in present-day developed societies. Thus, we hope that the present findings stimulate future investigations to combine evolutionary and sociological perspectives with each other, as an interdisciplinary approach may help to achieve a more comprehensive picture of human social behavior.

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Table 1. Descriptive statistics

	No. of obs.	No. of person	%	Mean	SD
Respondent's age	2,502	1,366		41.9	6.09
Respondent's education					
Primary or lower secondary level	197	96	7.8		
Upper secondary level	1,516	823	60.6		
Lower degree level tertiary education	699	397	27.9		
Higher degree level tertiary education or PhD	90	50	3.6		
Respondent's financial condition					
Low income	687	349	27.5		
Middle-income	1,260	688	50.4		
Comfortable or wealthy	555	329	22.2		
Respondent's number of siblings	2,502	1,366		2.9	2.24
Gender constellation of sibling pairs					
Female-female	838	458	33.5		
Male-male	396	216	15.8		
Mixed	1,268	692	50.7		
Age difference between siblings (years)	2,502	1,366		6.2	4.35
Parenthood status of sibling pairs					
Both are childless	206	112	8.2		
Parent-childless dyad	1,067	583	42.7		
Both have children	1,229	671	49.1		
Genetic relatedness					
Full siblings	2,224	1,214	88.9		
Maternal half siblings	151	83	6.0		
Paternal half siblings	127	69	5.1		
Sibling's financial condition					
Low income	480	262	19.2		
Middle-income	1,072	585	42.9		
Comfortable or wealthy	950	519	38.0		
Geographical distance between siblings					
Less than 1 km	38	21	1.5		
1-5 km	196	107	7.8		
5-25 km	575	314	23.0		
25-100 km	563	307	22.5		
100-500 km	828	452	33.1		
More than 500 km	302	165	12.1		

Table 1 continued

Childhood co-residence duration					
No time at all	103	82	6.0		
Only for a short time	71	54	4.0		
Less than half of the time	138	93	6.8		
More than half of the time	493	388	28.4		
Entire time	894	749	54.8		
MPA					
Absent	1314	717	52.5		
Present	1188	649	47.5		
Contact frequency with sibling	2,502	1,366		2.1	1.13
Emotional closeness to sibling	2,502	1,366		2.7	0.99
Provision of help	2,502	1,366		0.4	0.49

Notes. No. of obs. = Number of total observations; No. of person = Number of unique individuals; SD = Overall standard deviation. Contact frequency varies from 0 (never) to 4 (several times a week), emotional closeness from 0 (very distant) to 4 (very close) and provision of help from 0 (none) to (has helped during the last 12 months). MPA = maternal perinatal association.

Table 2. Random- and fixed-effect regressions of associations between childhood proximity and sibling relationship quality

	Childhood co-residence duration and sibling relationship quality											
	Contact frequency				Emotional closeness				Provision of help			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	RE	SE	FE	SE	RE	SE	FE	SE	RE	SE	FE	SE
Childhood co-residence duration												
No time at all	ref		ref		ref		ref		ref		ref	
Only for a short time	0.18	0.143	0.32	0.173	0.23	0.14	0.39*	0.173	0.08	0.066	0.16*	0.079
Less than half of the time	0.26	0.141	0.49**	0.172	0.48**	0.138	0.72***	0.172	0.09	0.065	0.23**	0.079
More than half of the time	0.43**	0.138	0.57**	0.174	0.52***	0.134	0.75***	0.174	0.14*	0.064	0.23**	0.08
Entire time	0.57***	0.14	0.73***	0.178	0.66***	0.136	0.85***	0.178	0.15*	0.065	0.23**	0.082
	MPA and sibling relationship quality											
MPA												
Absent	ref		ref		ref		ref		ref		ref	
Present	0.29***	0.044	0.31***	0.058	0.25***	0.043	0.31***	0.058	0.09***	0.02	0.10***	0.027

Notes. RE = random effect, FE = fixed-effect, MPA = maternal perinatal association;

RE: n = 2,502 observations of 1,366 unique individuals;

FE: n = 1,871 observations of 735 unique individuals;

* p < .05, ** p < .01, *** p < .001

Table 3. Fixed-effect regressions of associations between childhood proximity and sibling relationship quality including interaction terms between childhood coresidence duration and MPA, childhood coresidence duration and gender constellation, and MPA and gender constellation

		Model 1		Model 2		Model 3	
		β	SE	β	SE	β	SE
Contact frequency	Childhood co-residence duration	0.13**	0.04				
	MPA	1.06***	0.30				
	Childhood co-residence duration x MPA	-0.22**	0.08				
	Childhood co-residence duration			0.13**	0.04		
	Gender constellation			-0.48***	0.12		
	Childhood co-residence duration x Gender constellation						
	MPA			0.01	0.04	0.34***	0.07
	Gender constellation					-0.40***	0.06
	MPA x Gender constellation					-0.10	0.09
Emotional closeness	Childhood co-residence duration	0.15**	0.04				
	MPA	1.10***	0.30				
	Childhood co-residence duration x MPA	-0.23**	0.08				
	Childhood co-residence duration			0.14**	0.04		
	Gender constellation			-0.48***	0.12		
	Childhood co-residence duration x Gender constellation						
	MPA			0.05	0.04	0.29***	0.07
	Gender constellation					-0.33***	0.06
	MPA x Gender constellation					0.03	0.09
Provision of	Childhood co-residence duration	0.03	0.02				

help	MPA	0.38**	0.14				
	Childhood co-residence duration x MPA	-0.08*	0.04				
	Childhood co-residence duration Gender constellation			0.06**	0.02		
	Childhood co-residence duration x Gender constellation			0.06	0.06		
	MPA					-0.05**	0.02
	Gender constellation						
	MPA x Gender constellation						
							0.13***
						-0.06**	0.03
						-0.07	0.04

Notes. MPA = maternal perinatal association;
n = 1,871 observations of 735 unique individuals;
* p < .05, ** p < .01, *** p < .001

Table 4. Fixed-effect regressions of associations between genetic relatedness, childhood proximity and sibling relationship quality

(A) Genetic relatedness, childhood co-residence duration and sibling relationship quality												
	Contact frequency				Emotional closeness				Provision of help			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Genetic relatedness												
Full siblings	ref		ref		ref		ref		ref		ref	
Maternal half siblings	-0.41***	0.122	-0.28*	0.126	-0.34**	0.125	-0.18	0.128	-0.02	0.056	0.02	0.058
Paternal half siblings	-1.06***	0.12	-0.58**	0.181	-1.22***	0.123	-0.57**	0.184	-0.26***	0.056	-0.08	0.084
Childhood co-residence duration												
No time at all			ref				ref				ref	
Only for a short time			0.30	0.171			0.39*	0.173			0.16*	0.079
Less than half of the time			0.42	0.171			0.71***	0.174			0.21**	0.079
More than half of the time			0.54**	0.173			0.75***	0.175			0.23**	0.08
Entire time			0.67***	0.176			0.84***	0.179			0.21**	0.082
(B) Genetic relatedness, maternal perinatal association and sibling relationship quality												
	Contact frequency				Emotional closeness				Provision of help			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Genetic relatedness												
Full siblings	ref		ref		ref		ref		ref		ref	
Maternal half siblings	-0.32*	0.135	-0.25	0.134	-0.28*	0.134	-0.20	0.133	-0.02	0.061	0.01	0.062
Maternal perinatal association												
Absent			ref				ref				ref	
Present			0.29***	0.059			0.33***	0.059			0.10***	0.03

Notes. MPA = maternal perinatal association;

(A) n = 1,871 observations of 735 unique individuals;

(B) n = 1,711 observations of 685 unique individuals;

* p < .05, ** p < .01, *** p < .001

Appendix Table 1. Fixed-effect regressions of associations between childhood co-residence duration and MPA and sibling relationship quality

	Contact frequency		Emotional closeness		Provision of help	
	β	SE	β	SE	β	SE
Childhood co-residence duration						
No time at all	ref		ref		ref	
Only for a short time	0.29	0.17	0.38*	0.17	0.15	0.08
Less than half of the time	0.38*	0.17	0.67***	0.17	0.19*	0.08
More than half of the time	0.49**	0.17	0.70***	0.17	0.21**	0.08
Entire time	0.46*	0.18	0.61**	0.18	0.13	0.08
MPA						
Absent	ref		ref		ref	
Present	0.27***	0.06	0.30***	0.07	0.11***	0.03

Notes. MPA = maternal perinatal association;
n = 1,871 observations of 735 unique individuals;
* p < .05, ** p < .01, *** p < .001

Appendix Table 2. Fixed-effect regressions of associations between covariates and sibling relationship quality

	Contact frequency		Emotional closeness		Provision of help	
	β	SE	β	SE	β	SE
Gender constellation of sibling pairs						
Female-female	ref		ref		ref	
Male-male	-0.52***	0.09	-0.46***	0.09	0.09*	0.04
Mixed	-0.61***	0.05	-0.46***	0.05	-0.06*	0.02
Age difference between siblings	0.001	0.01	0.003	0.01	0.004	0.003
Parenthood status of sibling pairs						
Both are childless	ref		ref		ref	
Parent-childless dyad	-0.11	0.08	-0.06	0.08	-0.05	0.04
Both have children	-0.21	0.11	-0.20	0.11	-0.14**	0.05
Genetic relatedness						
Full siblings	ref		ref		ref	
Maternal half siblings	-0.41**	0.12	-0.34**	0.12	-0.02	0.06
Paternal half siblings	-1.06***	0.12	-1.22***	0.12	-0.25***	0.06
Sibling's financial condition						
Low income	ref		ref		ref	
Middle-income	0.02	0.06	0.16*	0.06	0.01	0.03
Comfortable or wealthy	0.05	0.07	0.18**	0.07	0.02	0.03
Geographical distance between siblings						
Less than 1 km	ref		ref		ref	
1-5 km	0.10	0.22	0.07	0.22	0.07	0.10
5-24 km	-0.14	0.20	0.003	0.20	-0.04	0.09
25-100 km	-0.42*	0.20	-0.03	0.20	-0.08	0.09
100-500 km	-0.61**	0.20	-0.04	0.21	-0.17	0.09
More than 500 km	-0.75***	0.21	-0.22	0.21	-0.25*	0.10

Notes. n = 1,871 observations of 735 unique individuals;

* p < .05, ** p < .01, *** p < .001

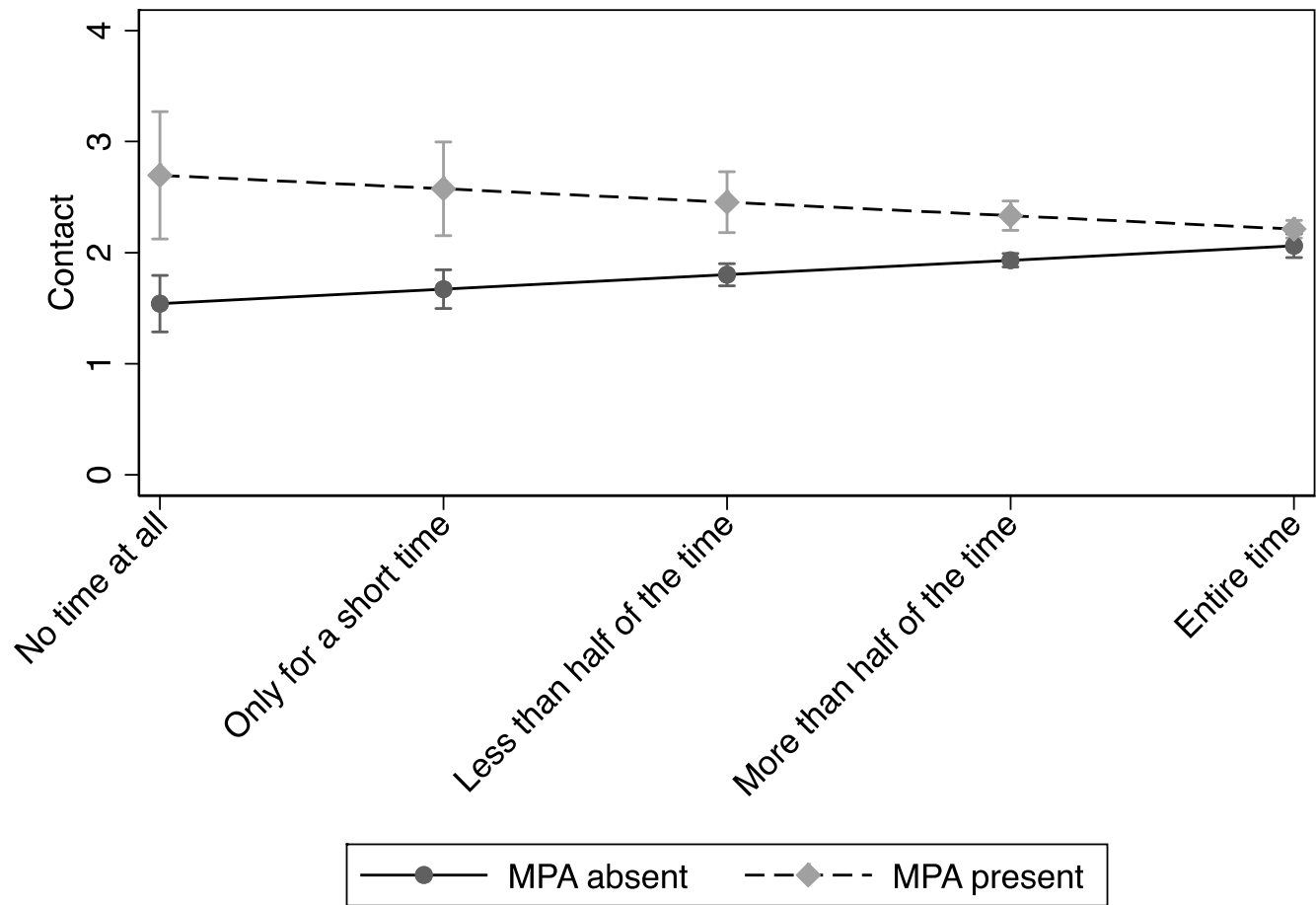


Figure 1. Associations between childhood co-residence duration and sibling contact frequency in adulthood by maternal perinatal association (predictive margins and 95% confidence intervals), entire time is 18 years (see Table 3 for statistical details).

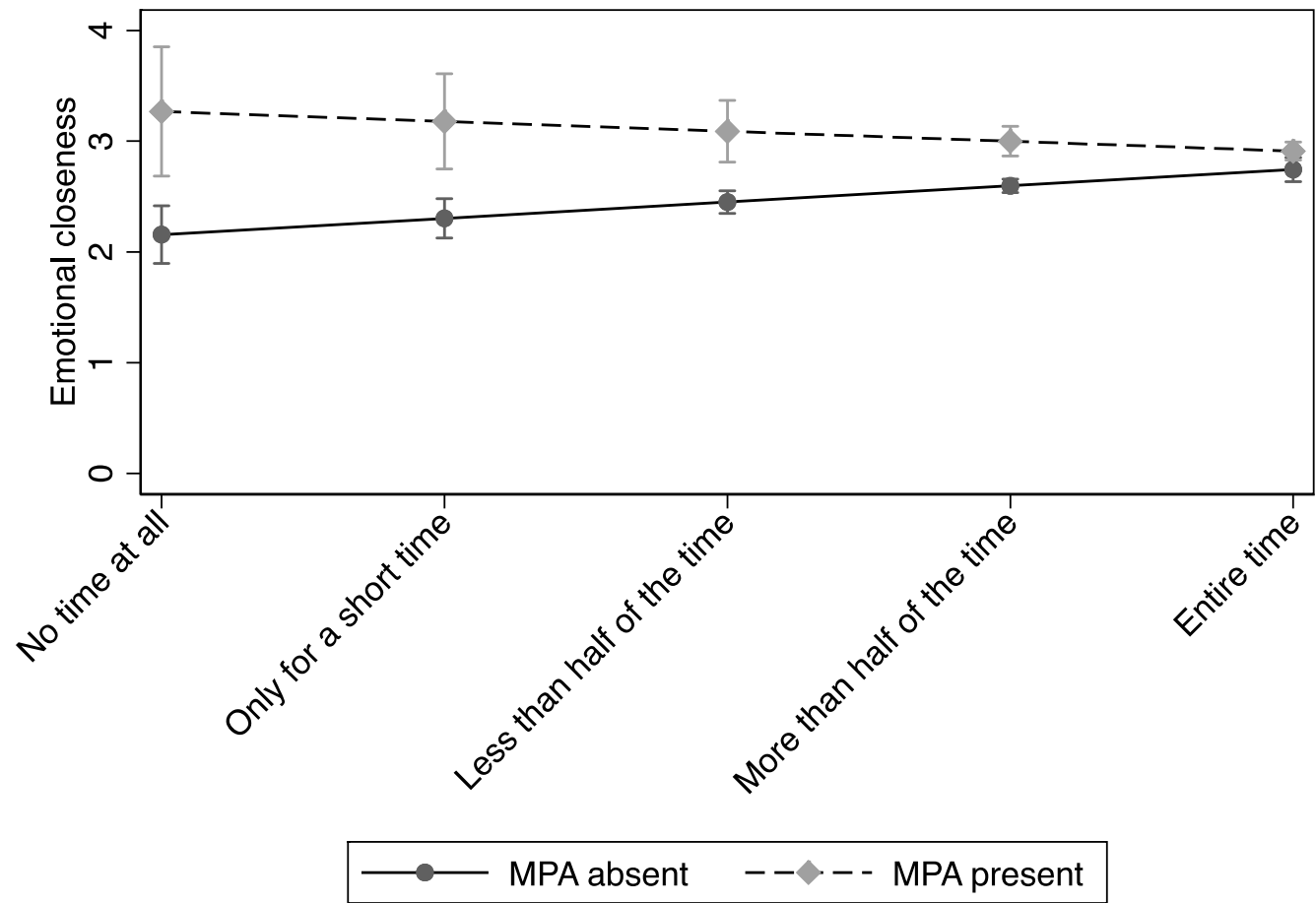


Figure 2. Associations between childhood co-residence duration and sibling emotional closeness in adulthood by maternal perinatal association (predictive margins and 95% confidence intervals), entire time is 18 years (see Table 3 for statistical details).

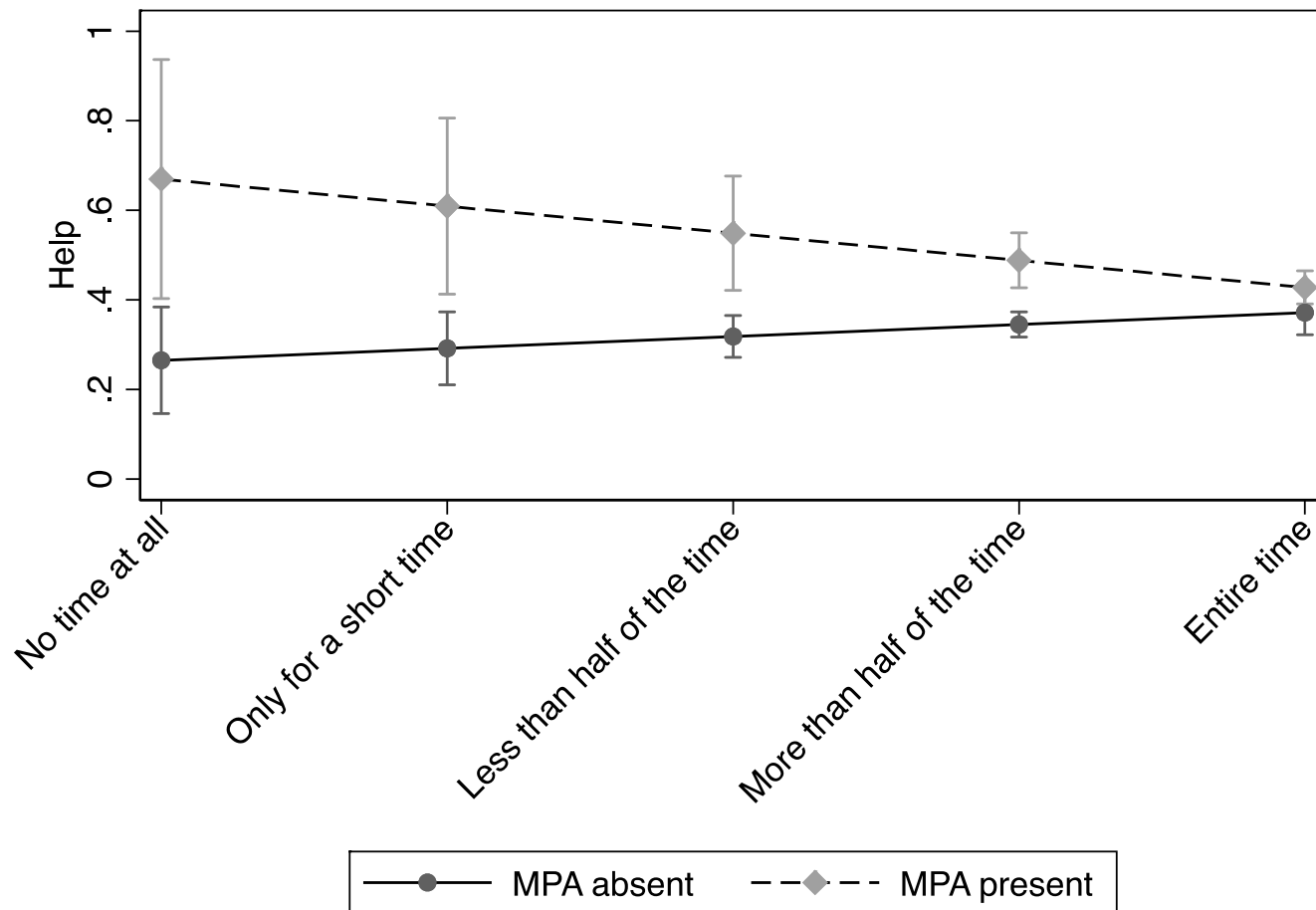


Figure 3. Associations between childhood co-residence duration and sibling provision of help in adulthood by maternal perinatal association (predictive margins and 95% confidence intervals), entire time is 18 years (see Table 3 for statistical details)

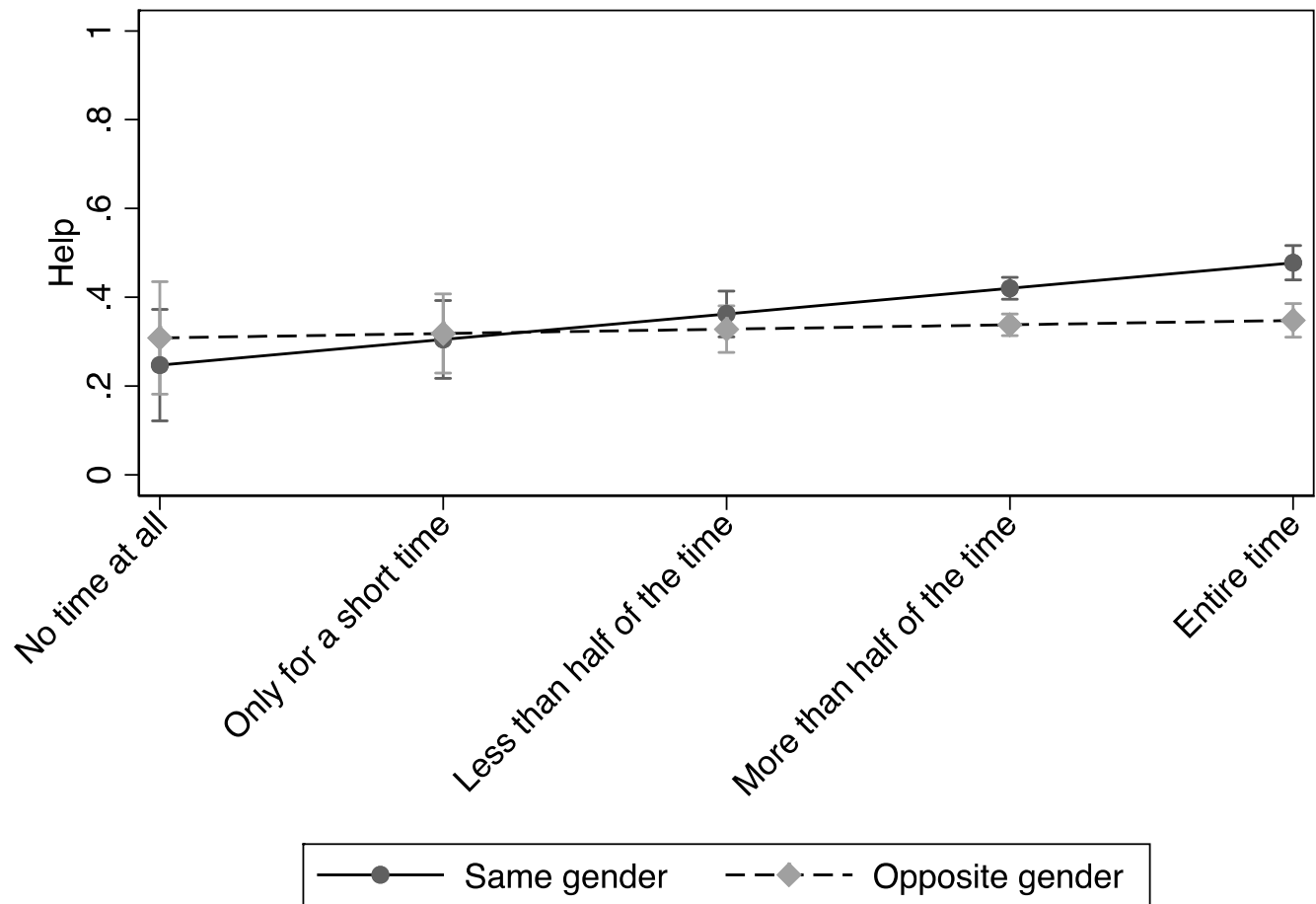


Figure 4. Associations between childhood co-residence duration and sibling provision of help in adulthood by gender constellation of siblings (predictive margins and 95% confidence intervals), entire time is 18 years (see Table 3 for statistical details)