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Genetic relatedness and sibling relationship characteristics in a modern society

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Abstract

Evolutionary theory predicts that relatedness will affect family relationships. Previous studies on siblings have mainly focused on sibling differentiation, sibling rivalry, and incest avoidance, and very few have examined the impact of genetic relatedness on the sibling relationship. Using a large data set from the Netherlands (Netherlands Kinship Panel Study), I show that relatedness (full vs. half-sibling) independently influences social investments between siblings. Maternal half-siblings, who are raised together like full siblings (FS), were found to show significantly lower levels of investment than FS. This suggests that a psychological mechanism besides childhood proximity regulates investment in the sibling relationship. Yet, levels of investment were overall higher for maternal than paternal half-siblings, suggesting an important role for childhood co-residence. Results are discussed with reference to kin selection theory.

Keywords: Siblings; Kin selection theory; Genetic relatedness; Family relationships

1. Introduction

Recently, individualization theorists, for example, Giddens (1991) and Beck (1993), have argued that social and family relationships have become increasingly dependent on individual choice rather than traditional norms and structures. According to this view, genetic relatedness only plays a minor role for kin and family relationships in modern societies. Although some theorists acknowledge that members of 'patchwork' families might have to work harder to overcome familial problems (Beck-Gernsheim, 1998), it is implicitly and sometimes explicitly assumed that genetic relatedness plays virtually no role for modern family relationships.

Evolutionists, by contrast, predict that genetic relatedness will affect family relationships in both traditional and modern societies (Hamilton, 1964; Emlen, 1995, 1997).

Anthropological studies have shown that in traditional societies, closer related kin more often provide (mutual) material and immaterial support than distantly related kin, all else being equal. Closer related individuals are generally more likely to form coalitions for conflicts than distantly or unrelated individuals (Yanomamö: Chagnon & Bugos, 1979; Norse Earldoms, Icelandic families and English royalty: Johnson & Johnson, 1991; Viking Sagas: Dunbar, Clark, & Hurst, 1995). Besides forming coalitions for conflict, closely related kin often cooperate to overcome what is known as 'the dilemma of collective action' (Olson, 1965). Kin in traditional societies often help each other without requiring a direct return for the given help to a relative. By contrast, help from unrelated individuals appears to be based on direct reciprocity. This has been shown for agricultural tasks, for example, among the Ye'kwana of Venezuela (Hames, 1987) and the K'ekchi of Belize (Berté, 1988), and for hunting (Inuit: Morgan, 1979; but see Alvard, 2003). Closely related kin also often share meat as well as other food items (Cashdan, 1985; Betzig & Turke, 1986; Gurven, Hill, Kaplan, Hurtado, & Lyles, 2000; Gurven, 2004). An analysis of worker remittances in a modern society showed that closely related kin are more likely to receive money than distantly related kin (Bowles & Posel, 2005). In addition, individuals appear more willing to incur significant 'costs' for closely related individuals than for distantly related or unrelated individuals (Burnstein, Crandall, & Kitayama, 1994; Madsen et al., in press). However, this effect of relatedness on altruistic behavior

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appears to be mediated by emotional closeness (Korchmaros & Kenny, 2001). Incurring costs to aid closely related kin, rather than distantly related or unrelated individuals, is also more likely to be deemed rational and ethical (Kruger, 2001). Kinship cues, sharing the same last name (Oates & Wilson, 2002) for example, have been shown to facilitate altruism. Other kinship cues such as olfactory cues (Wedekind & Furi, 1997), facial resemblance (DeBruine, 2002, 2004a,b, 2005), attitude similarity (Park & Schaller, 2005), and co-residence (Fessler & Navarrete, 2004; Lieberman, Tooby, & Cosmides, 2003) thoroughly affect the evaluation of and interaction between individuals.

Kin also make up a significant proportion of one's social network (Dunbar & Spoors, 1995; Hill & Dunbar, 2003). In traditional societies, closer related individuals have been shown to interact more often with each other than distantly related kin (Hames, 1979). Similarly, genetic relatedness is a significant predictor of subjective closeness and social support in modern societies (Neyer & Lang, 2003). The important role of kin for social support (e.g., Miller & Darlington, 2002; Kana'Iaupuni, Donato, Thompson-Colon, & Stainback, 2005) could lead to inclusive fitness benefits, even in modern societies.

Thus, studies from a kin selection perspective show that biological kinship ties can heavily influence cooperation and (mutual) investments between individuals in terms of material and social support. However, relatively few studies have examined the effect of genetic relatedness on sibling relationships, especially in contemporary societies. While there has been considerable research on parent–offspring relations in patchwork families (Daly & Wilson, 1981, 1982, 1985, 1988; Cherlin & Furstenberg, 1994; Stewart, 2005; Zvoch, 1999), the study of sibling relationships within these families has been largely neglected. Evolutionary analyses of sibling relationships so far have mainly focused on sibling differentiation (Dunn & Plomin, 1991; Plomin & Daniels, 1987), sibling rivalry (Sulloway, 1996, 2001), and incest avoidance (Aoki, 2005; Bevc & Silverman, 1993, 2000; Fessler & Navarrete, 2004; Lieberman et al., 2003).

Emlen (1997) suggested that individuals will invest more in full siblings (FS) than in half-siblings or stepsiblings. Sibling ties are predicted to be weaker and display more conflict when siblings are not fully related. In line with this prediction, parents and children report more conflict when siblings are not fully related than when they are fully related (Hetherington, 1988; Aquilino, 1991 for a review). Jankowiak & Diderich (2000) found that, despite a strong cultural ideology for equal treatment of half-siblings, half-siblings displayed significantly lower solidarity than FS in a polygamous Mormon community.

However, besides genetic relatedness, social factors, such as age or gender, heavily determine relationship dynamics between adult siblings (White & Riedmann, 1992). Research has shown that women act as kin keepers (Fischer, 1982; Lee, Mancini, & Maxwell, 1990; Rosenthal, 1985; White & Riedmann, 1992). Therefore, women are predicted to have stronger relationships with their siblings. Similarity should also influence relationship strength: the more similar the individuals in a sibling dyad are, the stronger their relationship is predicted to be (see McPherson, Smith-Lovin, & Cook, 2001). Following individualization theory, higher educated individuals are predicted to be less concerned with their sibling than lower educated individuals (see Beck & Beck-Gernsheim, 2002). Following exchange theory (Homans, 1951, 1958), financial relationships between siblings should also mirror social relationships. Balanced relationships and relationships without conflicts should be stronger and show more social investments (see Blau, 1964, but see Molm, 1997).

Predictions from these theories are not at odds with an evolutionary analysis of sibling ties, but are necessary as they address other aspects of sibling relationships. My analysis focuses on one aspect of sibling relationships (Jankowiak & Diderich, 2000), namely, social investments by siblings in each other. Social investment refers to keeping in contact and showing concern. Showing concern is necessary to assess the state of the sibling relationship. Although the costs of these social investments are probably not very high, they do represent a cost in terms of time and also an opportunity cost. Moreover, these social investments reflect relationship strength, and possibly a willingness to incur costs.

My hypothesis is that evolved psychological mechanisms regulating nepotistic investment independently affect the social investments made by siblings. Sibling dyads where the siblings are not fully related are predicted to display lower rates of social investment in one another. No study so far has investigated the independent effect of psychological mechanisms governing nepotistic investment on the sibling relationship while controlling for social factors.

There is however an alternative hypothesis, namely, that growing up together is the only important factor for the strength of the sibling dyad and that other evolved psychological mechanisms, such as third-party knowledge, play no role. Two distinct perspectives lead to this hypothesis. Identification theory (Stets & Burke, 2000) would lead to predict that growing up together increases sibling dyad strength because individuals will be more likely to categorize themselves as family members and behave accordingly. A kin recognition perspective suggests that propinquity during childhood is an important cue for identifying and interacting with kin (Fessler & Navarrete, 2004; Lieberman et al., 2003). I deal with this alternative hypothesis in two ways. Firstly, I control for age difference. The larger the age difference, the less likely that siblings will have shared childhood experiences. Secondly, I will compare maternal and paternal half-siblings (PHS). Children are more likely to remain with their mother if parents separate (De Graaf, 1997). Therefore, maternal half-siblings (MHS) are more likely to have been raised together than PHS. If differences with fully related siblings are found, not only for PHS but also for MHS, I can conclude that a

Table 1
Variables, categories, and predictions

Variables	Categories	Prediction
Educational attainment of respondent[1,2,3]	Eight categories (from incomplete/primary to university/postgraduate)	Less contact if higher educated
Difference in educational attainment between siblings[1,2,3]	Seven categories (treated as interval)	Less contact if large difference
Age difference between siblings[1,2,3]	Interval (difference in birth years)	Less contact if large difference
Age respondent (at interview)[1,2,3]	Interval	Less contact if older
Gender of the respondent[1,2,3]	0=male; 1=female	More contact if female
Gender of sibling A[1,2,3]	0=male; 1=female	More contact if female
Living full, half-, and adopted siblings[1,2,3]	Interval	Less contact if more siblings
Sibling type[1,2,3]	1=PHS 2=MHS 3=FS	More contact if fully related, MHS will have more contact than PHS
Financial balance[1]	1=respondent gives more; 2=other gives more 3=balanced	More contact if balanced
Financial help given[1]	0=yes; 1=no	More concern if money given
Financial help received[1]	0=yes; 1=no	More concern if money received
Initiative contact [1]	1=usually my initiative; 2=usually other's Initiative; 3=more or less equal	More contact if balanced
Conflict[1]	1=not at all; 2=once or twice; 3=several times	More contact if no conflicts
Geographical distance[3]	Interval	Less contact if distance increases
Concern given and received[1,2]	1=given and received not at all 2=given once or twice; received not at all 3=given several times; received not at all 4=given not at all; received once or twice 5=given and received once or twice 6=given several times; received once or twice 7=given not at all; received several times 8=given once or twice; received several times 9=given and received several times	(dependent variable)
Face-to-face contact[3]	1=never; 2=once; 3=several times 4=at least monthly; 5=at least weekly; 6=several times a week or daily	(dependent variable)

Superscripts 1–3 specify in which analysis the variable is used. Geographical distance is used only in the second model of Analysis 3.

psychological mechanism besides childhood propinquity influences sibling ties. Thus, if while controlling for age difference, I find a consistent difference between MHS and FS, this is reasonably strong evidence for the existence of another psychological mechanism regulating investment in kin rather than shared childhood experiences.

2. Methodology

The first wave of the Netherlands Kinship Panel Study (NKPS) data set was obtained through the Netherlands Interdisciplinary Demographic Institute. The NKPS is a large-scale longitudinal study, designed to investigate family and kin relations in the Netherlands (Dykstra et al., 2004). The first wave was completed mid-2004; I used the most recent version of the first-wave data set for this study (version of 21-7-05; main sample). The sampling procedure, representativity, as well as the survey method are described in detail by Dykstra et al.

In the NKPS, questions were asked about 'sibling A', a randomly selected sibling of the respondent (n=7544). Sibling A was a full, half-, or adopted sibling of the respondent.[1] As in only 19 cases, sibling A was an adopted sibling; this category was excluded from the analyses. Therefore, the analyses include three categories for sibling type, fully related (n=7265), PHS (n=134), and MHS (n=126). In order to test the assumption that children are more likely to live with their mother than with their father, I will analyze all family transitions as reported by respondents until they were 16 years old.

Correspondent characteristics of sibling A, for example, gender, were associated by use of the sibling identification code (see Dykstra et al., 2004). The variables selected for analyses are presented in Table 1. The correspondent questions and additional information can be found in the NKPS codebook (Dykstra et al., 2004), except for the constructed variables (age difference, education difference, gender of sibling A, total living siblings, sibling type, education difference). Age difference was calculated as the absolute difference in birth years between siblings; it is therefore an approximation. Education difference is the

[1] Due to the setup of the data set, sibling A could not be a step-sibling of the respondent: sibling A was a full, half-, or adopted sibling.

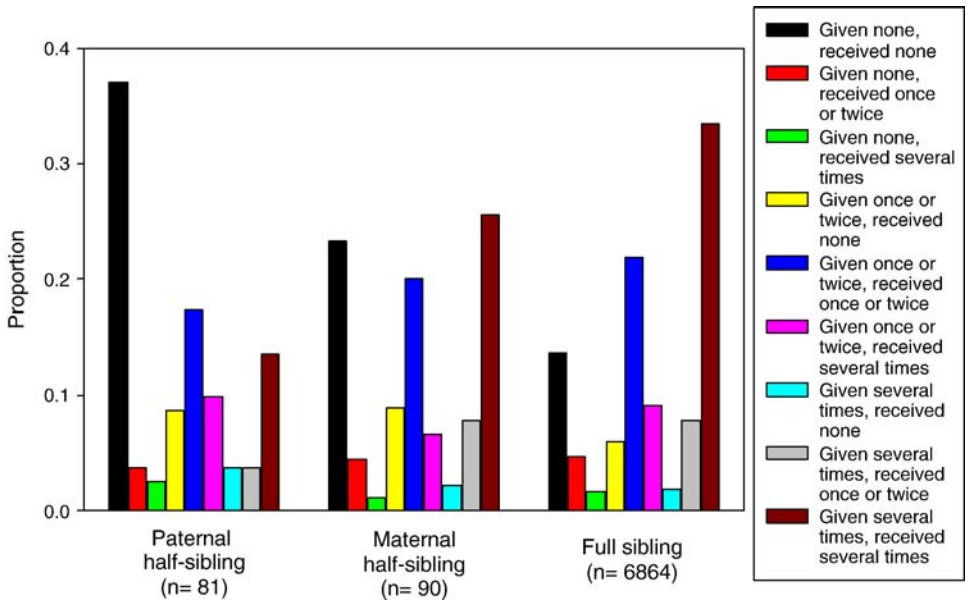

Fig. 1. Sibling type and concern given and received over the past 3 months ($\chi^2=55.4$, $df=16$, $p=3.05\times10^{-6}$).

absolute difference between the respondent and sibling A in educational attainment categories, with a high score indicating a strong dissimilarity.

It is important to note that nearly 7% did not respond on the questions concerning relationship with sibling A (financial balance, financial help given, financial help received, initiative contact, conflict, concern given, and received). The questions for these variables were not asked if the respondent did not have any face-to-face contact with his or her sibling A over the past 12 months. Therefore, I will include a second analysis where I have added a category 'missing' (Analysis 2). This category indicates that the respondent has not been in contact with his/her sibling over the past 12 months. In order to confirm the findings of Analysis 2, I use a measure for face-to-face contact ($n=7406$; Analysis 3). A first model does not control for geographical distance, as for more than 10% of the respondents these data are lacking. A second model including a Euclidean distance measure allows estimating the effect for relatedness while controlling for the effect of distance (see Dykstra et al., 2004).

For the analyses, I will thus use 'concern given and concern received' (Analyses 1–2) and then face-to-face contact as a dependent measure (Analysis 3). Both measures reflect social investment. Multinomial logistic regression (MLR) was used to investigate the independent effect of genetic relatedness on the dependent variable (Hosmer & Lemeshow, 1989; Menard, 1995; Pampel, 2000). Multinomial logistic regression as statistical technique is relatively free of assumptions and statistically robust. Unlike ordinary least square regression, parameters are estimated by maximum likelihood. As a parameter selection procedure, forward stepwise was used. Model outcomes were only marginally different in terms of model fit and Nagelkerke (1991) R^2 when backward stepwise was used instead. Here I will report the likelihood ratio (LLR) tests for variables in the model and parameter estimates (see Peng, Lee, & Ingersoll, 2002). As many independent variables are used, I will not discuss all effects. I focus on the independent effect of genetic relatedness. For each MLR, the parameter estimates for PHS or MHS are provided if significantly different from FS. I present Wald statistics and p values for the LLR tests. The Wald statistic allows examining the significance of single parameters (Pampel, 2000). The p value for LLR is based on a χ^2 test statistic: the difference between the reduced, that is, without a certain variable, and the final model in terms of −2 log likelihood (−2LL) (Pampel, 2000). The χ^2 test is set against the null hypothesis that all parameter estimates corresponding to a variable equal zero. These values are therefore the same for different parameter estimates from the same MLR.

3. Results

3.1. Assumption

Respondents who were not living with both natural parents at birth were significantly more likely to live in a family structure with their biological mother, that is, mother only or mother and stepfather, than in a family structure with their biological father (binomial test: $p=2\times10^{-15}$). For all family transitions until 16 years old, respondents were more likely to live with a family containing their biological mother than in a family with their biological father (all binomial tests: $p<.005$).[2]

[2] I did not analyze family transitions containing less than 0.5% of the total sample ($n=37$).

Table 2
Parameter estimates for concern given and received none (vs. given and received several times)

Concern given	None							
Concern received	None	λ	S.E.	Wald	*df*	p_{Wald}	Exp (λ)	p_{LLR}
Intercept		−7.67	1.62	22.34	1	<.001		
Sibling type	PHS	1.63	0.41	15.50	1	<.001	5.12	.04
	MHS	0.60	0.34	3.19	1	.074	1.83	
	FS	0			0			
Education	Incomplete/primary	1.44	0.21	46.44	1	<.001	4.22	<.001
	Lower vocational	1.55	0.18	71.14	1	<.001	4.72	
	Lower general secondary	1.19	0.19	37.40	1	<.001	3.28	
	Medium general secondary	0.65	0.25	6.83	1	.009	1.92	
	Upper general secondary	0.44	0.27	2.81	1	.094	1.56	
	Intermediate vocational	0.89	0.17	26.17	1	<.001	2.43	
	Higher vocational	0.46	0.17	6.96	1	.008	1.58	
	University or postgraduate	0			0			
Financial balance	Respondent gives more	1.12	0.31	12.94	1	<.001	1.95	<.001
	Other gives more	0.45	0.29	2.34	1	.126	1.57	
	More or less equal	0			0			
Initiative contact	Usually my initiative	0.66	0.20	11.27	1	<.001	2.29	<.001
	Usually other's initiative	−0.17	0.18	0.89	1	.346	0.84	
	More or less equal	0			0			
Conflict	Not at all	−1.03	0.28	13.61	1	<.001	0.36	<.001
	Once or twice	−1.32	0.32	17.24	1	<.001	0.27	
	Several times	0			0			
Age difference	(change by one year)	0.03	0.01	7.47	1	.006	1.03	.014
Gender of sibling A	Female	−0.80	0.08	90.65	1	<.001	0.45	<.001
Number of siblings	(change by one sibling)	0.12	0.02	43.44	1	<.001	1.12	<.001
Gender respondent	Female	−1.08	0.09	159.21	1	<.001	0.34	<.001
Age	(change by one year)	0.01	0.00	19.25	1	<.001	1.01	<.001
Financial help received	No	1.57	0.61	6.64	1	.010	4.80	<.001
Financial help given	No	1.96	0.53	13.67	1	<.001	7.12	<.001

Parameter estimates are set to 0 for reference categories.

3.2. Analysis 1: concern given and received over the past 3 months

Fig. 1 shows that in more than 35% of the PHS dyads, siblings did not show any concern for each other. For MHS dyads, nearly one quarter was unconcerned for each other, while nearly 15% of the dyads where siblings are fully related showed this lack of concern for each other.

The variables listed with superscript '1' in Table 1 were used for the model. Education difference did not independently influence the likelihood of giving and receiving concern in the MLR. Sibling type proved to be a significant independent predictor of concern given and received ($-2LL=23447.56$, $\chi^2=27.17$, $df=16$, $p=.04$). The model consisting of these predictors has a Nagelkerke R^2 of .207, which is good according to standards in the social sciences (model fit: $-2LL=23420.39$, $\chi^2=1525.67$, $df=176$, $p<.0001$).

Parameter estimates for not having given any concern and not having received any concern vs. having given and received concern are presented in Table 2. The Wald statistic allows examining the significance of single parameters (Pampel, 2000). Parameter estimates are best interpreted in terms of odds ratios or Exp(λ), which allows examining effect size. The odds are the probability of category membership Xi divided by the probability of membership of the reference category. For instance, the odds, that is, the probability of not having given and received any concern for their sibling vs. the probability of having given and received concern several times, for respondents who have a brother as sibling A are 2.22 times[3] the odds for respondents who have a sister. This effect is found while controlling for the other variables in the model. If this is phrased differently: respondents are 2.22 times more likely to not have given and received any concern instead of several times over the past 3 months if they have a brother instead of a sister. For the discussion of the results I use this shorthand version, yet it is important to bear in mind that 'times more likely not to have given and received any concern' refers to a comparison between categories in terms of odds. Thus, respondents are significantly more likely to have given and received concern several times over the past 3 months by their sibling vs. not at all, if their sibling was a sister instead of a brother. An example of an odds ratio for an interval variable, an 'increase of one sibling,' has an odds ratio of 1.12. For each sibling the respondent has apart from sibling A, it becomes 1.12 times more likely that he or she has not given and received any concern, instead of having given and received concern several times over the past 3 months.

[3] 2.22=1/0.45; reference categories can be 'switched' by inverting parameter estimates.

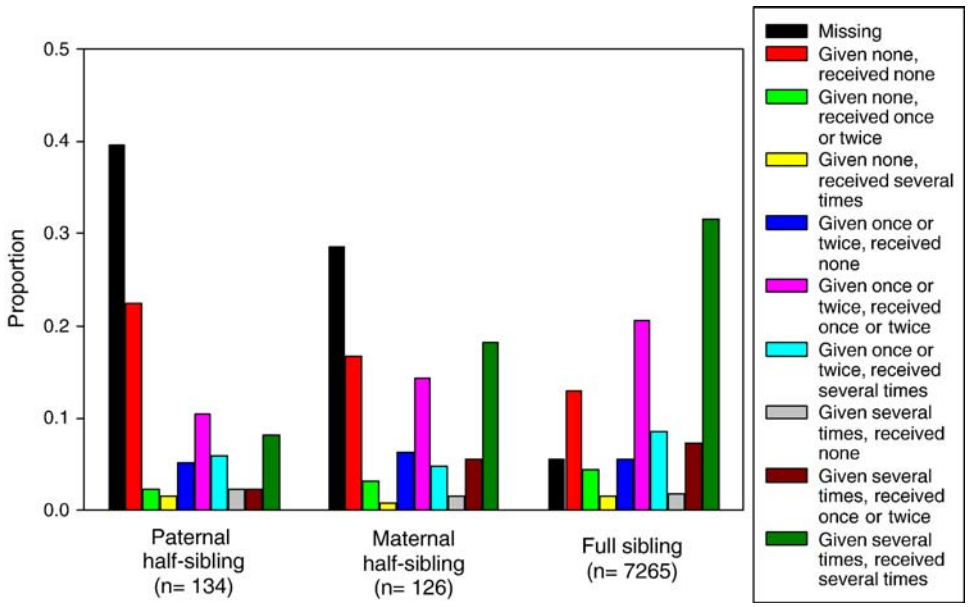

Fig. 2. Sibling type and concern given and received (including missing) over the past 3 months ($\chi^2=144.28$, $df=18$, $p=9.54\times10^{-22}$).

Paternal half-siblings are 5.12 times more likely not to have shown any concern for their sibling, instead of several times, over the past 3 months than FS. MHS are 1.83 times more likely not to have shown any concern for their sibling, instead of several times, than FS. These effects for PHS and MHS are found while controlling for the other variables in the model. Yet, the difference between MHS and FS is not significant at the 5% level [95% confidence interval for Exp(λ), 0.94–3.55].

Respondents are 3.46 times more likely to state they have shown concern once or twice while their sibling showed no concern for them, instead of both siblings having shown concern several times over the past 3 months, if they are PHS than if they are FS ($p_{\text{Wald}}=.018$; table not shown). Respondents are 5.97 times more likely to state they have shown concern several times while their sibling showed no concern for them, instead of both siblings having shown concern several times, if they are PHS than if they are FS ($p_{\text{Wald}}=.012$; table not shown).

3.3. Analysis 2: concern given and received over the past 3 months (including missing)

For nearly 40% of the PHS, there were no data available on concern in each other, indicating that these persons did not have contact over the past 12 months (Fig. 2). For MHS there were no data available for 30% of the dyads. Only 5%

Table 3
Parameter estimates for concern given several times and received missing (vs. given and received several times)

Concern given	missing							
Concern received	missing	λ	S.E.	Wald	df	p_{Wald}	Exp (λ)	p_{LLR}
Intercept		−3.83	0.35	119.68	1	<.001		
Relatedness	PHS	2.65	0.39	46.56	1	<.001	14.13	<.001
	MHS	1.82	0.31	34.66	1	<.001	6.16	
	FS	0			0			
Education	Incomplete/primary	1.70	0.30	33.08	1	<.001	5.47	<.001
	Lower vocational	1.64	0.28	34.98	1	<.001	5.16	
	Lower general secondary	1.25	0.29	18.62	1	<.001	3.48	
	Medium general secondary	0.97	0.36	7.38	1	.007	2.65	
	Upper general secondary	0.45	0.38	1.37	1	.243	1.56	
	Intermediate vocational	1.04	0.27	15.08	1	<.001	2.84	
	Higher vocational	0.65	0.27	5.79	1	.016	1.92	
	University or postgraduate	0			0			
Education difference	(increase by one category)	0.07	0.03	4.55	1	.033	1.07	.001
Age difference	(increase by one year)	0.05	0.01	14.44	1	<.001	1.05	.009
Gender of sibling A	Female	−0.51	0.11	21.30	1	<.001	0.60	<.001
Number of siblings	(increase by one sibling)	0.07	0.02	10.84	1	.001	1.08	<.001
Gender respondent	Female	−0.79	0.11	47.57	1	<.001	0.46	<.001
Age	(increase by one year)	0.03	0.00	69.90	1	<.001	1.03	<.001

Parameter estimates are set to 0 for reference categories.

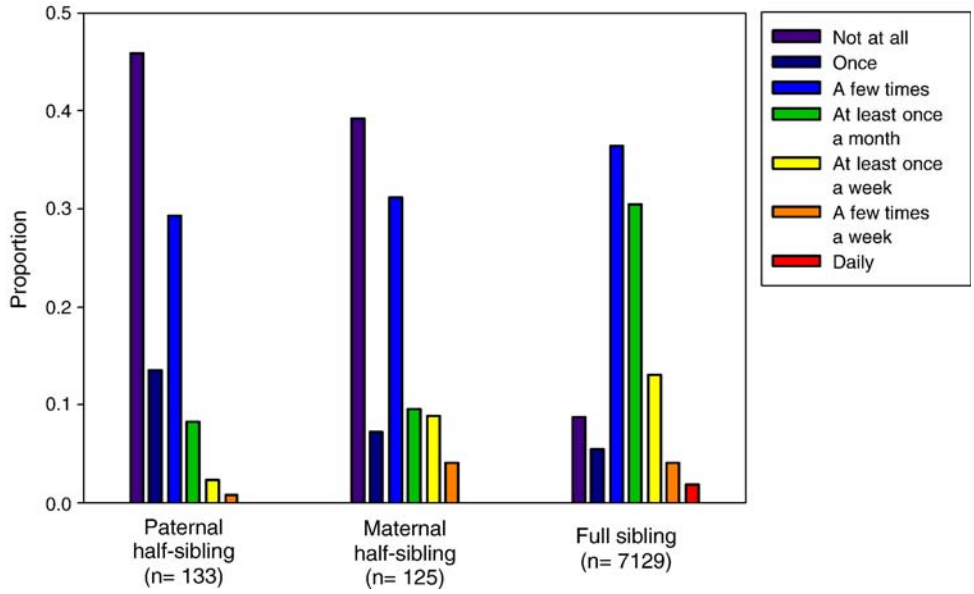

Fig. 3. Sibling type and face-to-face contact over the past 12 months (Somers' $Dyx = 0.483$, $p = 1.19 \times 10^{-28}$).

of the FS did not have any data on concern given and received. This indicates that PHS and MHS are more likely not to have had any contact with their sibling over the past 12 months.

All variables indicated with superscript '2' in Table 1 proved significant predictors for concern given and received. Sibling type proved to be a highly significant independent predictor of concern given and received ($-2LL = 27314.87$, $\chi^2 = 100.81$, $df = 18$. $p = 1.57 \times 10^{-13}$). This model has a Nagelkerke R^2 of .154 (model fit: $-2LL = 27214.06$, $\chi^2 = 1198.83$, $df = 135$, $p < .0001$) (Table 3).

Data are 14.13 times more likely to be missing, instead of indicating 'giving and received several times' for PHS than for FS. For MHS, data are 6.16 times more likely to be missing than indicating that concern was given and received several times over the past 3 months than for FS. This indicates PHS and MHS are more likely not to have been in contact over the past 12 months with their sibling than FS. Respondents are 4.81 to have shown and received no concern if they are PHS than if they are FS ($p_{Wald} < .001$; table not shown). If respondents are MHS they are 1.90 times more likely not to have shown or received any concern than if they are FS ($p_{Wald} = .049$; table not shown). The odds ratio for concern given once or twice but received none for PHS is 3.32 ($p_{Wald} = .017$; table not shown). For concern given several times but received none the odds ratio for PHS is 5.16 ($p_{Wald} = .016$; table not shown).

Table 4
Parameter estimates for face-to-face contact not at all (vs. daily or several times a week)

Face-to-face contact	Not at all	λ	S.E.	Wald	df	p_{Wald}	Exp (λ)	p_{LLR}
Intercept		−1.84	0.40	21.76	1	<.001		
Sibling type	PHS	3.41	1.03	10.90	1	.001	30.22	<.001
	MHS	1.81	0.49	13.52	1	<.001	6.11	
	FS	0			0			
Education	Incomplete/primary	−0.55	0.33	2.76	1	.097	0.58	<.001
	Lower vocational	−0.83	0.30	7.54	1	.006	0.43	
	Lower general secondary	−0.54	0.31	2.96	1	.085	0.58	
	Medium general secondary	−0.28	0.38	0.54	1	.462	0.76	
	Upper general secondary	−0.49	0.41	1.43	1	.232	0.61	
	Intermediate vocational	−0.66	0.29	5.28	1	.022	0.52	
	Higher vocational	−0.08	0.30	0.08	1	.779	0.92	
	University or postgraduate	0			0			
Education difference	(increase by one category)	0.09	0.04	5.55	1	.018	1.09	.017
Age difference	(change by one year)	0.03	0.02	3.51	1	.061	1.03	.015
Gender of sibling A	Female	−0.44	0.13	11.36	1	.001	0.65	<.001
Number of siblings	(change by one sibling)	0.05	0.03	2.88	1	.090	1.05	.007
Gender respondent	Female	−0.47	0.13	12.07	1	.001	0.63	.002
Age	(increase by one year)	0.07	0.01	160.76	1	<.001	1.07	<.001

Parameter estimates are set to 0 for reference categories.

3.4. Analysis 3: face-to-face contact over the past 12 months

In line with Fig. 2, over 40% of the PHS did not have any face-to-face contact with their sibling. Nearly 40% of the MHS did not have any face-to-face contact with their sibling, while only 10% of the FS did not have any contact. Only fully related siblings indicated they had face-to-face contact on a daily basis (Fig. 3). Therefore, this category was merged with 'several times a week' for the MLR.

All variables indicated with superscript '3' in Table 1 proved significant predictors for face-to-face contact. The model has a Nagelkerke R^2 of .142 (model fit: $-2LL=20843.99$, $\chi^2=1043.46$, $df=75$, $p<.0001$) (Table 4).

PHS are 30.22 times more likely than FS not to have had any contact instead of having contact daily or several times a week. MHS are 6.22 times more likely than FS not to have had any contact instead of having contact daily or several times a week.

PHS are also 20.5 times more likely than FS to have had contact once and 7.99 times more likely than FS to have had contact several times instead of daily or several times a week ($p_{Wald}=.004$ and .043, respectively; tables not shown).

Controlling for geographical distance improves the model fit (model fit: $-2LL=16714$, $\chi^2=2194.92$, $df=75$, $p<.0001$, Nagelkerke $R^2=.306$). After controlling for distance, age difference is not a significant predictor (at $\alpha=.05$). In this model, the odds ratios for having face-to-face contact not at all, instead of a few times a week or daily, are 22.48 for PHS and 8.84 for MHS vs. FS ($p_{Wald}=.003$ and $<.001$, respectively; tables not shown). The odds ratio for having contact 'once' instead of a few times a week or daily for PHS vs. FS is 17.18 ($p_{Wald}=.009$; table not shown). Unlike for the first model, for MHS the odds ratio for once, instead of a few times a week or daily, is significant ($p_{Wald}=.015$, odds ratio=4.93; table not shown). For PHS the odds ratio for 'several times', instead of daily or several times a week, is not significant anymore ($p_{Wald}=.071$; table not shown).

4. Discussion

The results clearly show that the type of sibling dyad independently and quite strongly influences the social dynamics of the sibling dyad. Social factors also heavily determine the mutual social investments in the dyads. This is evident from the difference in Nagelkerke R^2 between Analysis 1 and Analysis 2. In line with social exchange theory, balanced relationships were stronger and financial investments mirrored social investments. Also, the more similar siblings are, the stronger their relationship. In line with previous findings on women as kin keepers, women are significantly more likely to maintain stronger relationships with other kin (Fischer, 1982; Lee et al., 1990; Rosenthal, 1985; White & Riedmann, 1992). As found in previous research (Lee et al., 1990), there is also some support for the finding that sister–sister dyads are stronger than sister–brother or brother–brother dyads. Contrary to the argument that kinship ties become less important with rising education (Fischer, 1982; Treas & Bengston, 1987; see Beck & Beck-Gernsheim, 2002), in this sample, higher educational attainment appears to lead to more social investment by siblings.

However, while controlling for these other factors affecting the sibling dyad (Table 1), there is an independent effect for sibling type. Consistent with our hypothesis, not only PHS but also MHS, who are likely to have been raised together, displayed lower rates of social investment than FS. This finding suggests that a psychological mechanism besides childhood propinquity, such as third-party knowledge, affects investment in siblings. Yet, for all analyses, the odds ratios for MHS vs. FS dyads were much weaker than for PHS vs. FS dyads, underlining the importance of cohabitation during childhood for sibling relationships (see Lieberman et al., 2003). Interestingly, PHS are significantly more likely than FS to claim there is an imbalance in their relationship, that is, that they show concern without receiving any concern. Yet, no such effect is found for MHS. This can be interpreted as PHS reporting a worse relationship than MHS and FS.

One of the drawbacks of this study is that self-reported, rather crude, measures of investment and survey measures for genetic relatedness were used. Moreover, it is unclear whether or not the observed differences in sibling relations have any measurable effect on inclusive fitness in modern societies. This study did not include any data on relations between step-siblings. Although previous research has shown that sibling dyads within stepfamilies display more conflict (Hetherington, 1988), it is unclear whether these sibling relations are significantly different from half-sibling dyads.

Consistent with previous findings (Hames, 1979; Hill & Dunbar, 2003) and with Emlen's (1997) prediction, I conclude that siblings interact significantly less if they are not fully related, all else being equal. Given that there are significant differences between MHS and FS, it appears that another psychological mechanism besides childhood propinquity regulates investment in siblings. Co-residence during childhood does play an important role, however, with PHS showing less interaction than MHS. These findings appear robust and cannot be attributed to other social factors (Table 1). Contrary to the individualization perspective on the family (Beck & Beck-Gernsheim, 2002; Beck-Gernsheim, 1998), genetic relatedness still influences relationship dynamics between siblings.

5. Conclusion

Contrary to the assumptions of individualization theory of the family, genetic relatedness (still) strongly influences the frequency of interaction between siblings. Sibling dyads where the siblings are not fully related displayed lower rates

of social investment. It appears that besides childhood co-residence another psychological mechanism regulates investment. Yet, cohabitation during childhood is an important determinant of the social dynamics between siblings in adult life, given that PHS displayed much lower social investment than MHS. This effect of genetic relatedness, mediated by childhood cohabitation, on social investment appears robust and cannot be attributed to other social factors influencing the sibling dyad.

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