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Original Article

Do grandparents favor granddaughters? Biased grandparental investment in UK☆,☆☆

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Abstract

Differential grandparental investment in grandchildren is often explained with paternity uncertainty. The asymmetric inheritance of the sex chromosomes, especially of the X chromosomes, may also bias grandparental investment. Recent studies show that ignoring the sex of the grandchild can mask important differences in the investment patterns of the same grandparent category, but this has not been tested in contemporary societies with nationally representative data. With 17 variables from the Involved Grandparenting and Child Well-Being 2007 survey, we tested differential grandparental investment as reported by British and Welsh adolescents and compared predictions based on X-chromosomal relatedness with predictions based on paternity uncertainty. The theories are expected to differ with regard to grandmaternal investment in grandsons and granddaughters. We test whether paternal grandmothers invest (H1) more in granddaughters than in grandsons, (H2) more in granddaughters than maternal grandmothers do and (H3) less in grandsons than maternal grandmothers do. In addition, following the suggestion that paternal grandmothers may reduce sibling competition between girls and boys by harming grandsons, we study whether (H4) paternal grandmothers channel more noninvestment into grandsons than into granddaughters. The results show no convincing support for the type of sex discrimination of grandchildren that is predicted by X-chromosomal relatedness theories, but do provide support for the paternity uncertainty theory. X-chromosomal relatedness does not appear to shape grandparental behavior in developed societies.

Keywords: Grandparent; Grandchild; Sex chromosome; Paternity uncertainty

1. Introduction

According to kin selection theory (Hamilton, 1964a, 1964b), grandparents may increase their reproductive success by investing in grandchildren, with whom they are on average genetically related to a degree of 25%. Grandparental investment may be understood as all actions and characteristics of grandparents that increase the fitness of a grandchild while detracting grandparents from other resource spending related to reproduction, survival, development and maintenance. Compared with parental investment, grandparental investment costs are typically lower, especially for postreproductive individuals, while its potential fitness benefits are high (Clutton-Brock, 1991; Euler, in press; Trivers, 1972). In traditional and subsistence societies, kin investment is usually measured as the effect of grandparental presence on child mortality (Mace & Sear, 2005; Sear & Mace, 2008). In developed societies with low infant and child mortality, grandparental investment is measured through variables assumed to improve the grandchild's well-being and security such as contact frequency, emotional closeness and financial assistance, as reported by the grandchildren, by their parents or by the grandparents themselves. Close grandparental contact appears to be especially important for adolescent coping in contemporary Western societies (Attar-Schwartz, Tan, Buchanan, Flouri, & Griggs, 2009).

Studies from both traditional and developed societies and using a wide range of variables show that grandparental

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investment is usually unequally distributed among grandchildren. Maternal grandmothers tend to invest the most and paternal grandfathers the least, while maternal grandfathers and paternal grandmothers invest either slightly different or equal amounts, depending on the measures used (e.g., Bishop, Meyer, Schmidt & Grey, 2009; Danielsbacka, Tanskanen, Jokela, & Rotkirch, 2011; Eisenberg, 1988; Euler, Hoier and Rohde, 2001; Euler & Weitzel, 1996; Griggs, Tan, Buchanan, Attar-Schwartz & Flouri, 2010; Kahana & Kahana, 1970; Laham, Gonsalkorale, & von Hippel, 2005; Mills, Wakeman, & Fea, 2001; Scholl Perry, 1996; Sear & Mace, 2008; Smith 1991; see Coall & Hertwig, 2010 and Euler, 2011, for review).

There is an intense discussion regarding the reasons for this bias. The prevailing view has postulated paternity uncertainty as the ultimate cause for differential grandparental investment. Nonpaternity rates for human societies are estimated to range from 2% to 3% in industrialized countries and probably reached somewhat higher levels in our evolutionary past, in any case, enough to drive selection pressures on paternal and kin behavior (Anderson, 2006; Bellis, Hughes, Hughes, & Ashton, 2005; Voracek, Haubner & Fisher, 2008; Voracek, Tran & Fisher, 2010). Grandparents should, other things being equal, evolve to prefer their genetically most certain grandchildren. Because only motherhood is totally genetically certain in humans, paternity uncertainty claims that the maternal lineage represents the most certain investment (Danielsbacka et al., 2011; Euler & Weitzel, 1996; Gaulin, McBurney, & Brakeman-Wartell, 1997, but see Pashos, 2000). Maternal grandfathers and paternal grandmothers each have one kinship link involving paternity uncertainty and are predicted to invest equally in grandchildren, especially when available investment outlets are taken into account (Bishop et al., 2009; Laham et al., 2005). A recent European study found clear support for this prediction: when paternal grandmothers lack a grandchild via a daughter, maternal grandfathers and paternal grandmothers look after the grandchild with the same intensity (Danielsbacka et al., 2011). The paternal grandfather has two potentially uncertain kinship links and is therefore expected to invest the least, which is in accordance with most empirical findings.

However, explanations based on paternity uncertainty ignore the sex of the grandchild. Do grandparents invest differently in granddaughters than in grandsons? Previous findings of sex-specific grandparental investment in modern societies are weak and mixed (see Euler, 2011, for review). Some studies have found granddaughters to reporting better relationship with grandparents than grandsons do (e.g., Creasey & Koblewski, 1991; Euler & Weitzel, 1996; Salmon, 1999), while others have detected a closer relationship in same-sex grandparent–grandchild dyads (Dubas 2001), and several studies found no evidence of sex discrimination by grandparents (e.g., Block, 2000; Höpflinger & Hummel, 2006; Mueller & Elder, 2003; Triado, Villar, Sole, Osuna, & Pinazo, 2005), prompting the extensive review by Coall and Hertwig (2010) to conclude that there is no convincing evidence of grandparental sex discrimination.

Recently, an interesting series of studies have asked how investment is affected by the different inheritance patterns of the sex chromosomes (Chrastil, Getz, Euler & Starks, 2006; Fox, Sear, Beise, Ragsdale, Voland & Knapp, 2010; Rice, Gavrilets, & Forsberg, 2010). A girl's X chromosome is identical to that of her paternal grandmother, while a boy's Y chromosome is identical to that of his paternal grandfather. The sex of the grandchild is therefore predicted to shape investment for specific grandchild–grandparent categories. This article explores whether X-chromosomal relatedness influences grandparental behavior in contemporary Europe.

2. Sex chromosome relatedness and grandparental investment

The genes on the X chromosome dramatically outnumber those carried by the Y chromosome, making the former a likely candidate for transmissions or mutations favoring biased investment in granddaughters. Chrastil and colleagues (2006) first proposed that discriminative grandparental investment should be influenced not only by paternal uncertainty but also by the asymmetric genetic relatedness between grandchildren and their maternal and paternal grandparents. In respect to autosome chromosomes, grandparents are equally related to grandchildren (putting paternity certainty into brackets), but this is not the case with sex chromosomes. A girl inherits one X chromosome from each parent. One is inherited from her father and through him from her paternal grandmother, while the other is inherited from her mother and contains genes from both the maternal grandmother and the maternal grandfather, due to genetic crossing over in the mother. Like the girl, a boy also has one X chromosome from his mother, which contains genes from both maternal grandparents. But the son inherits the entire Y chromosome from his father, who has inherited it from his paternal grandfather (Chrastil et al., 2006; Fox et al., 2010). Chrastil and colleagues (ibid.) hypothesized that biased investment would follow both the line of X-chromosomal inheritance (paternal grandmothers to granddaughters) and the line of Y-chromosomal inheritance (paternal grandfathers to grandsons). When testing these predictions with questionnaire data from contemporary German and US grandchildren, these authors found very little support for the sex chromosome hypothesis and concluded that paternity assurance overrides any sex chromosome effect in contemporary populations.

Recently, Fox and colleagues (2010) revived the sex chromosome hypothesis in relation to the X chromosome and the evolutionary importance of grandmothers. The genes on the X chromosome dramatically outnumber those carried by the Y chromosome, making the former a likely candidate for transmissions favoring biased investment in granddaughters.

The authors predicted that the paternal grandmothers will invest most in paternal granddaughters since this pair has the highest genetic coefficient of relatedness. Paternal grandmothers are also expected to invest least in their grandsons, with whom they share the smallest amount of genes compared with other grandparents and children. By contrast, maternal grandmothers are expected to invest equally in all grandchildren.

Fox and colleagues (2010) tested their hypotheses with data from seven traditional populations and found some evidence of preferential investment based on asymmetric X chromosome inheritance. However, only for two societies did the results reach statistical significance, and there were also notable and unpredicted investment differences. For all grandmother–grandchild dyads, the survival effects could be both negative and positive. The authors suggest that the mechanism driving differential investment due to X-chromosomal relatedness may be unconscious and stem from epigenetic inheritance or genetic imprinting. It is unclear how such nonbehavioral mechanisms would be activated only when the grandmother is physically present but not in her absence.

Finally, Rice and colleagues (2010) discuss the possibility of selfish mutations on the X chromosome. They first note that esteemed degrees of grandparent–grandchild overall genetic relatedness (between 23% and 27% multiplied with paternity assurance) are high and represent important investment incentive with regard to each grandchild. Nevertheless, sexually antagonistic (SA) zygotic drive on the X chromosome may lead to mutations that favor only X-related transmission. Such mutations are especially likely to evolve to influence the phenotype of the paternal grandmother. Interestingly, the SA zygotic drive is predicted to trigger not only granddaughter favoritism but also grandson harm by the paternal grandmother (see also Voland & Beise, 2002, 2005, for grandparental harm). As for the mechanism guiding discriminative grandparenting, Rice and colleagues (2010) speculate that behavior need not be conscious or overt, but harm could also result from negligence and inattentiveness.

In sum, the two theories based on X-chromosomal inheritance differ from paternity uncertainty theory in predicting that granddaughters should be favored by paternal grandmothers and from each other regarding the existence of direct grandparental harm. Significant influence of Y-chromosomal inheritance is not predicted by these theories, and the proximate mechanisms channeling behavior are unknown.

3. Hypotheses

We test hypotheses generated from the X chromosome theory and paternity uncertainty regarding preferential grandparenting. As discussed above, the hypotheses are partly overlapping, partly complementary and, in some cases, competing with each other (see the summary presented in Table 1). Based on possible effects of the X chromosome on sex-specific grandparental investment, we predict that:

(H1). Paternal grandmothers invest more in granddaughters than in grandsons.

(H2). Paternal grandmothers invest more in their granddaughters than maternal grandmothers do.

(H3). Maternal grandmothers invest more in grandsons than paternal grandmothers do.

Table 1
Predictions by paternity uncertainty and sex chromosomal explanations for biased grandparental investment and hypotheses studied

Theory	Paternity uncertainty (Euler & Weitzel, 1996; Laham et al., 2005)	Sex chromosomal selection (Chrastil et al., 2006)	X chromosome relatedness (Fox et al., 2010)	SA zygotic drive (Rice et al., 2010)
Cause of evolutionary pressure on grandparents	Paternity uncertainty biases grandparental investment toward available grandchildren with fewest uncertain kinship links, leading to a preference for matrilineal ties but no sex discrimination.	Asymmetrical inheritance of both the X and the Y chromosomes leads to sex-specific favoritism.	Expected overall relatedness is higher for X-chromosomal transmissions, leading to sex-specific favoritism.	Invasion of selfish mutations on the X chromosome leads to sex-specific favoritism and harm.
Predicted grandparental investment patterns	Investment amounts follow the pattern MGM>MGF>=PGM>PGF. PGM do not invest more in GD than in GS (indifferent to **H1**). PGM invest less than MGM in GD (**H2**, reversed). MGM invest more than PGM in GS (**H3**). PGM not predicted to harm GS (indifferent to **H4**).	PGM invest more in GD than in GS (**H1**). PGM invest more than MGM in GD (**H2**). MGM invest more than PGM in GS (**H3**). PGF invest more in GS than in GD. PGF invest more than MGF do in GS PGM not predicted to harm GS (indifferent to **H4**)	PGM invest more in GD than in GS (**H1**). PGM invest more than MGM in GD (**H2**). MGM invest more than PGM in GS (**H3**). PGM not predicted to harm GS (indifferent to **H4**).	PGM invest more in GD than in GS (**H1**). PGM invest more than MGM in GD (**H2**). MGM invest more than PGM in GS (**H3**). PGM harms GS but not GD, e.g., by withdrawing investment (**H4**).

Following the theory of SA zygotic drive, we further assume that noninvestment can be interpreted as a way to cause harm, for example, by reducing sibling competition, and predict that:

(H4). Paternal grandmothers more often withdraw investment from grandsons than they do from granddaughters.

Compared with X-chromosomal theories, paternity uncertainty does not predict any sex differences in H1 nor in H4 and makes the opposite prediction for H2. Only H3 is in line with the assumption based on all theories tested here. In addition, we tested for possible effects due to Y-chromosomal relatedness as originally predicted by Chrastil and colleagues (2006), and namely, that paternal grandfathers should invest more in grandsons than in granddaughters and that grandsons should receive more investment from paternal than from maternal grandfathers. Since this pattern has not found empirical support and is no longer theoretically proposed, we have not included these hypotheses in our main discussion.

4. Material, measurements and method

We study whether X-chromosomal effects on grandparenting are visible with large and representative data from a contemporary developed society. We use different measures of current contact, trust and importance attached by adolescents to their respective grandparents. In both traditional and modern societies, the effects of grandparents extend beyond early childhood and well into adolescence and adulthood (see, e.g., for traditional societies, Lahdenperä,

Table 2
Grandparental investment variables

	Scale in questionnaire				Dichotomized investment variable[a]	Dichotomized noninvestment variable[b]
1. How often do you see them?	Never	Several times a year	Once a week	Daily	1=weekly+, 0=other	1=never, 0=other
2. How often do your grandparents look after you?	Never	Several times a year	Once a week	Daily	1=weekly+, 0=other	1=never, 0=other
3. How much can you depend on your grandparent to be there when you really need him/her?	Not at all	A little	Sometimes	A lot	1=a lot, 0=other	1=not at all, 0=other
4. How much does your grandparent make you feel appreciated loved or cared for?	Not at all	A little	Sometimes	A lot	1=a lot, 0=other	1=not at all, 0=other
5. How happy are you with your relationship with your grandparent?	Very unhappy	Fairly unhappy	Fairly happy	Very happy	1=very happy, 0=other	1=very unhappy, 0=other
6. Compared with other grandchildren, (including your brother and sister), how close are you to your grandparent?	Less close than some or most	About the same	Closer than some	Closer than most	1=closer than most, 0=other	1=less close than some or most, 0=other
7. How often does your grandparent help you in important ways by giving you advice or helping solve problems you have?	Never	Rarely	Sometimes	Often	1=often, 0=other	1=never, 0=other
8. Do they get involved with things you like? For example sport, making things, doing things together?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
9. Do they come to school or other events that are important to you?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
10. How often do you talk to them about problems you have?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
11. Do you share things with them that you have not talked to your parents about?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
12. Can you talk to them about your future plans?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
13. Do they offer good advice when you have a problem?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
14. Do they give you money or help in any other way?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
15. Do they get involved in telling you what you can and cannot do?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
16. Do you respect what they say?	Never	Occasionally	Usually		1=usually, 0=other	1=never, 0=other
17. To what extent is your grandparent the most important person in your life outside your immediate family?	Not at all important	Not very important	Important person	Most important person in my life outside my family	1=most important person in my life …, 0=Other	1=not at all important 0=other

[a] For H1, H2 and H3.
[b] For H4.

Lummaa, Helle, Tremblay, & Russell, 2004, and for the contemporary UK, Attar-Schwartz et al., 2009). Close ties to adolescents also typically build on grandparental bonding formed when the grandchild was small. It is therefore reasonable to use adolescent's reports of received grandparental investment both as an indicator of ongoing investment and as general, albeit imperfect, indication of investments received in early childhood.

We use the Involved Grandparenting and Child Well-Being 2007 survey, which is the first nationally representative sample of British and Welsh adolescent aged 11–16 years (see also Attar-Schwartz et al., 2009; Tan, Buchanan, Flouri, Attar-Schwartz & Giggs, 2010; Griggs et al., 2010, who have used the same data). The sample was recruited by GfK (Growth from Knowledge) National Opinion Polls. Respondents completed the questionnaire in a school classroom. In every selected school, the classes were randomly chosen. Larger schools had greater probability to be included in the final sample. The resulting data include 1,488 adolescents who have at least one grandparent alive. When filling out the questionnaire, respondents were asked to answer questions for only those grandparents who were still alive. Seventeen variables (on a 3-point and 4-point scale) in the survey can be interpreted as measuring grandparental investment (see Table 2). We dichotomized these variables because we are interested in frequently provided grandparental investment (H1, H2 and H3) and withdrawal of grandparental investment (noninvestment) (H4). Very frequent investment has often been used to measure grandparental favoritism in contemporary societies (Euler, 2011). As the data do not include reports of abuse of other behavior directly indicating harm caused by a grandparent, we use lack of any investment as a measure of harm.

We also constituted a new data set in which the observations are the grandparents of the original respondents, resulting in a total of 4,177 observations (on average, 2.8 grandparents per respondent). This enables us to track the sex of respondents and the lineage of grandparents. The new grandparent–grandchild variable includes 8 dyads: maternal grandmother and granddaughter (MGM+GD), maternal grandmother and grandson (MGM+GS), maternal grandfather and granddaughter (MGF+GD), maternal grandfather and grandson (MGF+GS), paternal grandmother and granddaughter (PGM+GD), paternal grandmother and grandson (PGM+GS), paternal grandfather and granddaughter (PGF+GD) and paternal grandfather and grandson (PGF+GS). Five additional variables were formed for the analyses. The first is PGM+GD/PGM+GS, the second is MGM+GD/PGM+GD, the third is MGM+GS/PGM+GS, the fourth is PGF+GD/PGF+GS and the fifth is MGF+GS/PGF+GS.

The hypotheses were studied with logistic regression analysis, adjusting for several background variables known to affect grandparental investment (Euler & Michalski, 2008): age of respondent, number of living grandparents, age of grandparent, geographical distance between respondent and grandparent, grandparent's employment status, grandparent's marital status and grandparent's number of grandchildren. We included the "don't know" answers in the analysis since many respondents chose that option for some background variables (see Table 3).

5. Results

The first hypothesis predicts that paternal grandmothers invest more in their granddaughters than they do in their grandsons. Table 4 shows the likelihood of investment reported by grandsons and granddaughters for their paternal grandmothers. The granddaughter was chosen as the reference category, so that an odds ratio below 1 indicates lower investment from the paternal grandmother in grandsons than in granddaughters, and an odds ratio above 1 indicates the opposite. For the majority of the variables, the odds are less than 1 (10/17). There is thus a slight trend in support of granddaughter favoritism. However, the gender differences were not statistically significant, although they approached significance for questions number 7, 11 and 12 ($p<0.1$). Thus, boys were

Table 3
Descriptive statistics (%/mean) (basic data n=1,451–1,458; long-format data n=3,988–4,038)

	Granddaughter	Grandson
Respondent's age (years), mean	13.5	13.3
Number of living grandparents (mean)	2.8	2.8
Geographical distance between respondent and grandparent (%)		
Living together	2.3	1.9
In the same town	39.1	34.2
Within 10 mile	23.1	26.2
Further away (in the UK)	24.0	27.2
Further away (overseas)	8.0	7.6
Don't know	3.4	3.0
Age of grandparent (%)		
Younger than 50 years	0.8	0.8
In their 50s	10.7	9.4
In their 60s	41.8	39.6
Over 70 years	32.6	33.1
Don't know	14.1	17.1
Grandparent's employment status (%)		
Not working	63.2	65.2
Working part time	14.1	14.2
Working full time	10.5	10.6
Don't know	12.1	10.0
Grandparent's number of grandchildren (%)		
Respondent is only grandchild	3.4	2.6
2 or 3	24.5	28.9
4 or more	67.1	59.1
Don't know	5.0	9.4
Grandparent's marital status (%)		
Not married	13.9	13.6
Married	73.4	73.4
Remarried	7.0	5.2
Don't know	5.8	7.8

Basic data: age of respondent and number of living grandparents; long-format data: geographical distance between respondent and grandparent, grandparental age, employment status, health and number of grandchildren.

Table 4
Paternal grandmother investment in granddaughter and grandson (H1)

	OR	SE	*Z*	*p*	lb	ub	*n*
1. See gp	1.26	0.19	1.48	0.138	0.93	1.70	929
2. Gp look after r	0.97	0.17	−0.18	0.860	0.68	1.37	927
3. Gp be there for r	0.88	0.12	−0.90	0.370	0.67	1.16	923
4. Gp make r feel loved…	1.07	0.15	0.48	0.630	0.81	1.41	922
5. Happy with relationship with gp	1.12	0.16	0.83	0.407	0.85	1.47	930
6. Closeness compared…	0.76	0.13	−1.60	0.112	0.54	1.07	925
7. Gp help with problems	0.74	0.13	−1.78	0.077	0.52	1.03	927
8. Gp involve	0.96	0.16	−0.24	0.814	0.69	1.34	929
9. Gp come to events	0.71	0.15	−1.63	0.104	0.47	1.07	925
10. Talk about problems with gp	0.82	0.19	−0.89	0.375	0.52	1.28	924
11. Share things with gp	0.58	0.18	−1.77	0.076	0.31	1.06	925
12. Talk about future plans with gp	0.76	0.11	−1.92	0.054	0.54	1.01	927
13. Gp offer advice	1.12	0.16	0.78	0.438	0.85	1.47	921
14. Gp give money/help other way	0.85	0.11	−1.23	0.219	0.65	1.10	928
15. Gp tell what can do	1.07	0.17	0.45	0.654	0.79	1.47	921
16. Respect what gp say	1.06	0.15	0.39	0.696	0.80	1.40	920
17. Gp important person…	1.01	0.16	0.08	0.933	0.74	1.39	909

Abbreviations: lb, lower bound of confidence interval (95%); ub, upper bound of confidence interval (95%). Results of 17 logistic regression models measuring grandparental investment in grandchild. The main interpretative variable is the sex of the grandchild, and controlled variables in every model are age of the respondent, number of living grandparents, age of the grandparent, geographical distance between respondent and grandparent, grandparent's employment status, grandparent's marital status and grandparent's number of grandchildren. The reference category in the models is granddaughters. Odds ratio over 1 predicts greater investment in grandsons, and odds ratio less than 1 predicts greater investment in granddaughters.

somewhat more likely to report that his paternal grandmother discussed future plans and attended events, as the hypothesis predicts. Overall, the data do not provide strong support for sex discrimination by the paternal grandmother.

The second hypothesis predicts granddaughters to be more likely to receive greater investment from paternal grandmothers than from maternal grandmothers. The results are contrary to the hypothesis (see Table 5). In all questions, the odds demonstrate greater investment from maternal than from paternal grandmothers, and in almost all variables, the margins are statistically significant (1, 3, 4, 8, 9, 10, 12, 13, 14 and 17, $p<.001$; 5, $p=.001$; 2, 7 and 16, $p<.01$; 11 and 15, $p<.05$).

Table 5
Maternal grandmother and paternal grandmother investment in granddaughter (H2)

	OR	SE	*Z*	*p*	lb	ub	*n*
1. See grandparents (gp)	0.54	0.08	−4.22	.000	0.41	0.72	994
2. Gp look after grandchildren (r)	0.63	0.10	−3.03	.002	0.47	0.85	990
3. Gp be there for r	0.64	0.08	−3.66	.000	0.50	0.81	991
4. Gp make r feel loved …	0.55	0.07	−4.59	.000	0.43	0.71	991
5. Happy with relationship with gp	0.65	0.08	−3.48	.001	0.51	0.83	999
6. Closeness compared …	0.77	0.11	−1.83	.068	0.58	1.02	986
7. Gp help with problems	0.67	0.09	−2.90	.004	0.51	0.88	987
8. Gp involve	0.59	0.08	−3.73	.000	0.45	0.78	994
9. Gp come to events	0.58	0.09	−3.58	.000	0.43	0.78	995
10. Talk about problems with gp	0.47	0.08	−4.45	.000	0.34	0.65	991
11. Share things with gp	0.61	0.13	−2.26	.024	0.40	0.94	992
12. Talk about future plans with gp	0.67	0.07	−3.76	.000	0.54	0.82	997
13. Gp offer advice	0.62	0.07	−4.20	.000	0.49	0.77	991
14. Gp give money/help other way	0.65	0.07	−3.84	.000	0.52	0.81	996
15. Gp tell what can do	0.77	0.10	−1.99	.046	0.60	1.00	994
16. Respect what gp say	0.69	0.08	−3.10	.002	0.55	0.87	993
17. Gp important person …	0.58	0.07	−4.47	.000	0.45	0.73	987

Abbreviations: lb, lower bound of confidence interval (95%); ub, upper bound of confidence interval (95%). Results of 17 logistic regression models measuring grandparental investment in grandchild. The main interpretative variable is the type of the grandmother, and controlled variables are age of the respondent, number of living grandparents, age of the grandparent, geographical distance between respondent and grandparent, grandparent's employment status, grandparent's marital status and grandparent's number of grandchildren. The reference category in the models is maternal grandmother. Odds ratio over 1 predicts greater investment in granddaughters from paternal grandmother, and odds ratio less than 1 predicts greater investment in granddaughters from maternal grandmothers.

Table 6
Maternal grandmother and paternal grandmother investment in grandson (H3)

	OR	SE	Z	p	lb	ub	n
1. See grandparents (gp)	0.68	0.09	−2.95	.003	0.52	0.88	1047
2. Gp look after grandchildren (r)	0.58	0.08	−3.84	.000	0.44	0.77	1046
3. Gp be there for r	0.62	0.07	−4.20	.000	0.50	0.78	1043
4. Gp make r feel loved …	0.68	0.08	−3.24	.001	0.54	0.86	1036
5. Happy with relationship with gp	0.73	0.09	−2.58	.010	0.58	0.93	1042
6. Closeness compared …	0.73	0.10	−2.33	.020	0.55	0.95	1042
7. Gp help with problems	0.69	0.09	−2.87	.004	0.53	0.89	1046
8. Gp involve	0.80	0.10	−1.74	.083	0.61	1.03	1040
9. Gp come to events	0.52	0.08	−4.15	.000	0.38	0.71	1040
10 Talk about problems with gp	0.56	0.09	−3.50	.000	0.41	0.78	1035
11. Share things with gp	0.60	0.16	−1.93	.054	0.36	1.01	1037
12. Talk about future plans with gp	0.85	0.08	−1.68	.093	0.70	1.03	1036
13. Gp offer advice	0.73	0.07	−3.16	.002	0.60	0.89	1034
14. Gp give money/help other way	0.86	0.09	−1.42	.156	0.71	1.06	1038
15. Gp tell what can do	0.82	0.09	−1.87	.061	0.66	1.01	1031
16. Respect what gp say	0.78	0.09	−2.28	.022	0.63	0.97	1031
17. Gp important person …	0.67	0.08	−3.56	.000	0.53	0.83	1011

Results of 17 logistic regression models measuring grandparental investment in grandchild. The main interpretative variable is the type of the grandmother, and controlled variables are age of the respondent, number of living grandparents, age of the grandparent, geographical distance between respondent and grandparent, grandparent's employment status, grandparent's marital status and grandparent's number of grandchildren. The reference category in the models is maternal grandmother. Odds ratio over 1 predicts greater investment in grandsons from paternal grandmother, and odds ratio less than 1 predicts greater investment in grandsons from maternal grandmothers.

The third hypothesis, which predicts greater investment in grandsons from maternal grandmothers compared with paternal grandmothers, is clearly supported by the results (see Table 6). In all cases, the odds show greater investment from maternal grandmothers than paternal grandmothers in grandsons, and for most questions, the differences are statistically significant (2, 3, 9, 10 and 17, $p<.001$; 4, $p=.001$; 1, 7 and 13, $p<.01$; 5, $p=.01$; 6 and 16, $p<.05$).

Our fourth hypothesis predicts that paternal grandmothers channel more noninvestment into grandsons than into granddaughters. Contrary to the hypothesis, paternal grandmothers are more likely to withdraw investment from

Table 7
Paternal grandmother noninvestment in granddaughter and grandson (H4)

	OR	SE	Z	p	lb	ub	n
1. See gp	0.47	0.13	−2.69	0.007	0.27	0.81	929
2. Gp look after r	0.93	0.13	−0.52	0.604	0.70	1.23	927
3. Gp be there for r	0.72	0.13	−1.77	0.077	0.50	1.04	923
4. Gp make r feel loved …	0.45	0.12	−3.05	0.002	0.27	0.75	922
5. Happy with relationship with gp	0.52	0.14	−2.40	0.016	0.30	0.89	930
6. Closeness compared …	0.59	0.10	−3.03	0.002	0.41	0.83	925
7. Gp help with problems	0.66	0.11	−2.52	0.012	0.47	0.91	927
8. Gp involve	1.27	0.18	1.66	0.098	0.96	1.68	929
9. Gp come to events	0.98	0.14	−0.13	0.898	0.74	1.30	925
10 Talk about problems with gp	1.15	0.16	1.03	0.305	0.88	1.51	924
11. Share things with gp	1.03	0.16	0.17	0.862	0.75	1.40	925
12. Talk about future plans with gp	0.89	0.15	−0.71	0.476	0.65	1.23	927
13. Gp offer advice	0.68	0.11	−2.35	0.019	0.49	0.94	921
14. Gp give money/help other way	0.85	0.17	−0.83	0.406	0.58	1.25	928
15. Gp tell what can do	1.02	0.14	0.18	0.861	0.78	1.35	921
16. Respect what gp say	0.65	0.15	−1.88	0.060	0.42	1.02	920
17. Gp important person …	0.49	0.13	−2.62	0.009	0.29	0.83	909

Abbreviations: lb, lower bound of confidence interval (95%); ub, upper bound of confidence interval (95%). Results of 17 logistic regression models measuring grandparental noninvestment in grandchild. The main interpretative variable is the sex of the grandchild, and controlled variables are age of the respondent, number of living grandparents, age of the grandparent, geographical distance between respondent and grandparent, grandparent's employment status, grandparent's marital status and grandparent's number of grandchildren. The reference category in the models is granddaughter. Odds ratio over 1 predicts greater noninvestment in grandsons, and odds ratio less than 1 predicts greater noninvestment in granddaughters.

granddaughters than from grandsons (13/17) (see Table 7). In seven cases, the margins are significant (1, 4, 6 and 17, $p<.01$; 5, 7 and 13, $p<.05$). Girls especially often report no emotional closeness to their paternal grandmothers (seeing, feeling loved and close to, being happy with relationship) and no important interactions, such as receiving advice and help with problems.

Finally, we also tested for possible Y-chromosomal relatedness effects with negative results (tables not shown and available from the first author). When controlling for other factors, paternal grandfathers appeared to invest more in grandsons than in granddaughters (12/17). However, these margins were not statistically significant. Second, for all variables studied, maternal grandfathers showed greater likelihood to invest in grandsons compared with the investment by paternal grandfathers, and in many questions, the differences reached statistical significance (1, $p<.01$; 2, $p=.01$; 3, 4, 9, 11 and 16, $p<.05$).

6. Discussion

While it is clear that human grandparents bias investment in certain grandchildren more than in others, typically along the maternal lineage, the extent to which this also involves sex discrimination is being debated. We tested whether preferential grandparenting is based on paternity uncertainty and/or X-chromosomal effects with representative survey data from British and Welsh adolescents. Our measures included emotional, practical and financial forms of grandparental investment, and we controlled for various potential confounding variables in order to isolate the effects of grandparental lineage and grandchild sex.

Three hypotheses measured very frequent investments, while the fourth measured lack of investment, in what we believe is the first attempt to test X-related harmful grandparental behavior in relation to grandchild sex in an industrialized society. We found no convincing support for the hypotheses that relied on X-chromosomal effects only. When maternal grandmothers were compared with paternal grandmothers, the former were found to invest clearly more than the latter did in both grandsons and granddaughters. Paternal grandmothers did not significantly favor granddaughters over grandsons, nor did they withdraw investment more frequently from grandsons compared with granddaughters. The suggestion that grandson discrimination and granddaughter favoritism by paternal grandmothers would outweigh each other in studies that ignored grandchild sex was therefore not validated in our data. Our results are in concordance with Chrastil and colleagues (2006), who did not find sex chromosomal effects, although they used nonrepresentative survey data.

Interestingly, we found signs of sex discrimination from paternal grandmothers, albeit not as predicted by X-chromosomal relatedness. First, there was a slight, nonsignificant trend of granddaughter favoritism when we measured frequent investment provisions. Second, paternal grandmothers were more likely to invest nothing in granddaughters when compared with grandsons. If anything, paternal grandmothers in the UK therefore appear to discriminate against granddaughters. Of course, noninvestment in contemporary societies may be due to the grandparent being excluded from contacts with the grandchild in question. One possible interpretation is that total lack of investment would not be the choice (or harming intention) of the paternal grandmother, but result from a preference for maternal kin exhibited by the granddaughter (and possibly her mother).

In the future, sex-biased grandparental investment merits to be studied more precisely. Does the sex chromosome hypothesis receive support if the respondents are younger children in industrialized societies? What are the results if the respondents are the parents or grandparents? How does grandparental noninvestment vary between different grandparent–grandchild dyads? Finally, the sex chromosome hypotheses would merit to be explored together with preferential investment in more certain kin (Laham et al., 2005). A study based on the Survey of Health, Ageing and Retirement in Europe found that grandparents channel investment according to available outlets (Danielsbacka et al., 2011). Unfortunately, the Survey of Health, Ageing and Retirement in Europe data set does not include the sex of the grandchild as a variable, while the Involved Grandparenting and Child Well-Being 2007 survey used in this article does not include information about cousins in all parts of the questionnaire. Other studies are therefore needed in order to assess whether grandchild sex is a confounding variable in preferential grandparental investment in more certain kin.

7. Conclusions

In line with many other studies, the present findings from the contemporary UK do not show systematic variation in grandparental investment in relation to the sex of the grandchild. Sex chromosomal relatedness does not appear to shape grandparental behavior in developed societies. Our findings are consistent with effects predicted by paternity uncertainty.

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