Title: Kin effects or kin affected? - Differential mortality of reproductive females by family network composition

Author: Kai P. Willführ[╫] & Lisa Dillon[¥]

[╫] - Institute for Social Sciences, Carl von Ossietzky University, Oldenburg, Germany

[¥] - Université de Montréal, Canada

Introduction

Kin selection theory (Hamilton 1964) predicts a genetic conflict between reproductive females and the members of their in-law families. Because of the absence of inclusive fitness profits, altruistic behavior between genetically far or unrelated individuals is rare. There are at least three mechanisms connecting genetic conflict to increased mortality of reproductive women[1]. Firstly, the husband and his family face uncertainty about paternity. Therefore, the husband's family might invest fewer resources in the offspring of male family members than in the offspring of female family members where a blood relationship can be considered to be ensured (Danielsbacka et al 2011; Euler & Weitzel 1996; Gaulin et al. 1997). Secondly, because of the genetic distance between husband's wife and members of the in-law family, the in-law family lineage might tend to exploit the reproductive (Leonetti et al. 2007, Mace & Sear 2005) as well as the productive potential of husband's wife (Reid 2001). Thirdly, the mother-in-law might try to enhance her sons mating success by weaken the relationship between her son and his current partner. Thus, families may invest less in both the reproductive daughter-in-law and her offspring. The practice of patrilocality which is widespread among human societies might exacerbate potential negative in-law kin effects, because females living in the household of their husband's family cannot easily rely on support of their natal family.

---

[1] Being "reproductive" in this contexts means that these females are married and at fertile age.

However, studies which investigate kin effects on fertility and survival reveal mixed evidence (Rotering & Bras 2015) and therefore dispute the conclusion that natal kin represented a source of unconditional support and that in-law kin represented a source of unconditional competition. An earlier study on kin selection theory in the historical population of the Krummhorn region in East-Frisa (1720-1874) did not find increased mortality of reproductive females if these women lived with their in-laws. In addition, co-residence with the mother-in-law was associated with reduced not with increased mortality (Willführ et al. 2018). The positive effect of mothers-in-law was stronger among the economic elite. According to the authors, this might have been partially caused by significantly increased consanguinity among the landowning fraction of the population in order to concentrate property in the context of demographically saturated population (Johow et al. submitted). Consanguinity weakens in-law-conflicts substantially as, for instance; in cousin marriages one of the parents-in-law is a biological aunt or uncle. But also other factors might have contributed to the positive in-law effects. For example, living with a wealthy in-law family might offer more material resources and opportunities than living with the (poorer) natal family members. Following the authors' line of argumentation, the positive in-law effects in the Krummhörn region were essentially caused by social and economic conditions which either "solved" (consanguinity), compensated (greater economic opportunities in the household of the in-law family), or disguised (e.g. because of assortment effects or phenotypic correlation, see discussion section) the genetic in-law conflict. If the authors' interpretation is correct, then effects of in-law (as well as of natal) kin are highly affected and moderated by the socio-economic context and by population dynamics. From this is follows that the structure of kin network composition alone will not allow reliable predictions about the effect of kin, but might become possible, if important corner points of population are identified. We hypothesize that the level of demographic saturation and the accompanying factors like family size, the practice of consanguinity, and interfamily relationship building via exchange marriages are such important corner points.

In this paper we investigate kin effects in the historical population of the St. Lawrence valley in Quebec (New France, 1670-1799) by applying the same methods used by Willführ el al. (2018) in the Krummhörn region (1720-1874). The French settlers in the St. Lawrence Valley faced almost no land limitations and as a consequence there was no attempt at reducing family sizes, resulting in an average number of births of 10 to 11 births per woman (Charbonneau et al. 2000). In contrast, families of the Krummhörn region had almost no expansion possibilities and were characterized by comparatively low fertility. During the study period the Krummhörn region was demographically saturated and was characterized by a significant social stratification as is typical for early capitalistic agricultural societies (Knottnerus 2004; Voland & Dunbar 1995; Willführ & Störmer 2015). The differentials between the ecological environments of the Quebec and Krummhörn populations had also been previously used to investigate grandparental effects on child survival (Voland & Beise 2005), the consequences of parental loss and remarriage of the surviving parent on child survival (Willführ & Gagnon 2012, 2013), and the consequences of sibling formation on survival and reproductive success (Fox et al. 2016). We investigate alleged kin effect on three levels: Firstly, we investigate whether the presence of individual members of the natal and in-law family had an impact on the mortality of reproductive females. Secondly, we investigate whether the absolute size of natal and of the in-law family did matter and thirdly, we investigate whether the relative sizes of lineages at the parish level had an impact.

Material & methods

Study population: The St Lawrence Valley (Quebec) (1670–1799)

Data come from the Registre de la population du Québec ancien (RPQA), created by the Programme de Recherche en Démographique Historique (PRDH) at the University of Montreal. The RPQA is a family reconstitution database with more than 700,000 linked Catholic baptisms, marriages, and burials registered in the Quebec parishes of the St Lawrence Valley from settlement in 1621 up to 1799, as well as death records from 1800 to 1850 of persons who died at age 50+ years (Dillon et al., 2016). The population was very small at the beginning, with 3246 inhabitants at the time of the first census in 1666 (Charbonneau & Legare, 1967, p. 1033). With relatively low levels of immigration and only a minority of immigrants founding families within the colony, Quebec grew largely through natural increase, reaching a population size of more than 70,000 by 1760 (Charbonneau et al., 2000, p. 104). The database identifies both inter- and intragenerationally linked family members, and thus allows us to operationalize variables pertaining to life events of family members and the subject.

In contrast to the Krummhörn region, French settlers of Canada faced few land constraints. Patterns of settlement in the Quebec colony were initially circumscribed by dependence on the St Lawrence River for transportation and the need to avoid Amerindian raids, more frequent on the south side of the river (Laberge & Mathieu, 1996, p. 47). The western part of the St Lawrence region, around Montreal, was favored for settlement on account of its longer growing season and proximity to one of the two cities of the colony (Laberge & Mathieu, 1996, p. 48). As conflicts with Amerindians subsided, colonization progressed along both sides of the St Lawrence, creating a continuous series of settlements between Quebec City and Montreal (Laberge, Gouger, & Boisvert, 1996, p. 58). The majority of Quebec's inhabitants were farmers, with a smaller proportion of artisans, merchants, officers, professionals, and the ruling elite living in urban areas. Montreal and Quebec City were the only urban regions in the St Lawrence Valley, and nearly 80% of the children were born in the countryside. Along the banks of the St Lawrence River, development of the land was limited by the available workforce. Work to clear new land of trees, pull stumps, burn vegetation debris, remove rocks from the soil and create farm fields could take a French-Canadian family 15 to 20 years (Boudreau, Courville, & Séguin, 1997, p. 55). Inter- and intra-generational solidarity was necessary to achieve this goal. Quebec family solidarity is observed indirectly in a number of ways. For example, nearly a quarter of all families contracting marriages for their children between 1675 and 1799 contracted a marriage between sets of brothers and sisters, known as an 'exchange marriage' (Caron & Dillon, 2013, p. 14). The settlement of the St Lawrence Valley by families in extended kin groupings is evident in the concentration of particular last names within the seigneuries (Laberge & Mathieu, 1996, p. 53). Immigration of non-Catholic persons was extremely limited and marriage arrangements were therefore culturally endogamous (Charbonneau et al., 2000, pp. 110–111). Alongside the demands of settlement, Quebec society was dominated by both a strong Catholic church and a patriarchal family system which together enforced religious observance and paternal familial control, limiting the number of prenuptial conceptions and promoting high birth rates (Bates, 1986, pp. 263 and 268–269; Bouchard, 2000, p. 195; Cliche, 1988, p. 66).

The demands of settlement as well as conservative cultural expectations fostered early ages at marriage and high fertility. Individuals who belonged to a large sibship and who settled on the pioneer front tended to encourage the settlement of a large number of their own children in proximity. This led to an intergenerational transmission of total reproductive success in the colony (Gagnon & Heyer, 2001). Average ages at first marriage were especially low for the early cohorts, with mean age at marriage for women in 1660 being under 15 (Charbonneau et al., 2000). In addition, owing to their intense natural fertility regime as well as the resultant increases in population density, French Canadians exhibited relatively high infant mortality rates (Amorevieta-Gentil 2009).

Modeling kin effects

As in the previous study on the kin effect among the Krummhörn region (Willführ et al. 2018), we use Cox regression (Cox 1972, Allsion 2014) to model the life course of reproductive females from the date of their first marriage to the age of 45. Therefore, all women were married at the start of observation, but dependent on their husbands' survival they could have experienced episodes of widowhood and/or of remarriage within the study age range (see below). We choose date of first marriage as start of observation, because reproduction took place almost entirely within marriages. The age of 45 is widely used in female life course studies as an average age of menopause. Being reproductive in this context means that these women were at least once married before the age of 45. In estimating the kin effects on the mortality of reproductive women, we rely on a combination of models adjusted by clustering at the family level, and models stratified at the family level (family fixed effects) (Allison 2009). The former models investigate the general association between having kin and mortality among reproductive females, and thereby estimate the net result of kin effects. The latter models estimate likelihood functions with separate terms for each of the families in the dataset, and thus allow each family to have their own individual baseline hazard function. The key difference between the stratified and the clustered Cox regression models is that the stratified models identify kinship effects using the variation within families, but not between families. These stratified models control for unobserved heterogeneity if these factors were shared by sisters. By comparing the results of the clustered with the results of the stratified models we try to disentangle kin effects which were attributable to common causes from those which were directly linked to family members' behavior or accompanying factors. For example, having a large number of siblings could have been associated with reduced mortality due to parental characteristics (common cause) such as parental skills and the quality of the household, and not because of direct interactions between siblings. However, one disadvantage of the fixed-effect approach is that the models exclude singlets (in our case IDs without any reproductive sister in the dataset) from the analysis. Dependent on the structure of the data, the number of cases is therefore often substantially smaller in the fixed-effect version when compared to the clustered model version. Thus, if there are inconsistent findings in both model versions, it has to be tested whether this is due to the exclusion of cases or due to the different estimation of the likelihood function. This could be shown by re-running the cluster model versions with exact the same number of cases which are included in the fixed-effect approach.

The level of genetic relatedness might matter for family relationships. We therefore include information about the presence (see below) of each individual's natal and of in-law relatives. The time-varying data on the different individual family members are coded as dummy covariates. Each change in the kin composition (birth or death of an individual family member) is an event which brings a new episode of observation to the model. These linkages result in a large data setup; on average, there are almost 88 events for each woman between the date of her first marriage and the date of her exit from the sample (upon surviving to age 45 or prior death). Effects of kin belonging to the natal family are estimated based on all episodes, even if a woman was widowed or remarried. The impact of the in-law kin is, however, estimated only during a woman's first marriage. Episodes after the husband's death are excluded from the analysis, as it is unclear how the relationship between the reproductive woman and her in-law kin would have been affected by her husband's death or by her remarriage.

Since we are interested in analyzing both behavior-related kin effects that arise from direct social interaction and non-behavior-related (structural) kin effects, we need to disentangle these two types of kin effects. We would like to know whether the supposedly positive effect of being a member of a large family was the result of having a supportive and functional kin network, or was merely a reflection of the family's socioeconomic status. As behavioral effects applied only to family members with a certain level of spatial proximity, while structural kin effects did not require spatial proximity, we have created two sets of models to determine the significance of spatial proximity for kin effects. In the first set of models, we consider all living relatives, regardless of where they were residing. In the following, these models are referred to as "alive models." In a second set of models we include only relatives who were living in the same parish as the individual of interest. In the following, these models are referred to as "spatial models." In the spatial models, we assume that family members engaged in daily social interactions that had different effects on female mortality. In other words, for each woman and at every age, the alive models are able to determine how many relatives were alive, whereas the spatial models are able to determine whether these kin were living in the same parish. For all of the different models estimated, we include a set of covariates that control for potential confounding conditions based on the context into which a woman was born and was living. The primary variables of interest are those for kinship formation. The rest of the covariates are included because they may be correlated with both the dependent outcome and kin formation. These potential confounders are discussed in the paragraph below.

Women are especially vulnerable during postpartum periods (42 days after the birth). We therefore include a time-varying dummy covariate which indicates exposure to postpartum periods. We also include individual's birth cohort, which is coded in decades, to control for changes in the population over time, and for the individual's birth rank (Rutstein 1984).

For further details regarding the modeling strategies please see Willführ et al. (2018), page 6-8. The analyses in this paper are almost the same except that there is no information on family's socio-economic status (SES) in the St. Lawrence Valley. Therefore, we had to omit analyses which investigate the interaction between alleged kin effects and SES.

All analyses had been performed using R-3.4.1 with the help of the following packages: `data.table`, `reshape`, and `Hmisc` (includes `survival`).

Data selection criteria

We included females in analyses if they were born in the colony and if their parental marriages had been contracted between 1670 and 1730. An overview over the numbers of cases included is given in Table 1.

Results

Impact of the individual kin

A summary of the results of the Cox models for the impact of individual members of natal family is given in Table 2 and for the impact of individual members of the in-law family in Table 3. The spatial models only consider kin, if they lived in the same parish as the individuals of interest and the alive models consider any kin alive regardless his or her place of residence.

The models suggest that there was no statistically significant association between the mortality of reproductive females and members of the natal family, if they lived in the same parish. The only exception are biological mothers. Their presence in the same parish significantly reduced the mortality of their reproductive daughters (hazard rations 0.863* in the clustered and 0.654+ in the fixed-effect version of the spatial model). However, also the alive models which investigate the effect of kin alive without taking their spatial proximity into account suggest a positive effect of the biological mother (hazard rations 0.912** in the clustered and 0.726** in the fixed-effect version of the alive model). The results of the clustered and the fixed-effect alive models are not in agreement regarding the effect of having sisters. Whereas the clustered models indicated that there was a positive association between having sisters and survival (hazard ratio: 0.912**), the fixed-effect versions showed that having sisters was associated with a significant decrease in the likelihood of survival (hazard ratio 5.653***). The fixed alive model further reveals that fathers, brothers, and maternal aunts and uncles were associated with decreased mortality (hazard ratios: 0.782*, 0.746***, 0.755***, 0.865*).

Effects of individual kin who belong to the in-law family are rare. The fixed-effect version of the spatial model suggests that sisters-in-law and sisters of the mother-in-law were associated with reduced mortality (hazard ratios: 0.963+ and 0.935, respectively). The fixed version of the alive model suggest that the mortality of reproductive females was reduced when both parents of the husband were alive (hazard ratios: 0.887* and 0.886+, respectively).

Impact of lineage sizes

None of models which estimate the impact of the absolute size of lineages within the parish suggest that there was a significant association between lineage size and mortality of reproductive females (Table 4). The weighted and unweighted clustered alive model suggest that mortality was decreased by a large natal family, whereas the corresponding fixed-effect version of the models suggest an negative impact of the size of the natal family on mortality. However, the negative effects of the fixed-effect alive models are not detectable, if sisters are not considered in the lineage (see above).

The weighted fixed-effect spatial models which estimate the impact of the relative size of the lineages suggest that mortality of reproductive women was reduced if the lineages were equally sized (hazard ratio: 0.796*), the in-law lineages was larger (hazard ratio: 0.860+), and if only the in-law lineage was present in the parish (hazard ratio: 0.804+).

Discussion

In line with previous work by Willführ et al. (2018) using the historical population of the Krummhörn region in East-Frisia (Germany), we find mortality differentials of reproductive females in the St. Lawrence Valley in New France which were connected to the composition of the kin network. Although there are major differences in regard to these kin effects (see below), there are also some remarkable similarities between both populations. Not surprisingly biological mothers were associated with reduced mortality in both populations. This positive effect on reproductive daughters has often been reported for many historical and contemporary populations and is better known as the grandmother effect, and constitutes an expression of behavior-related kin support. Similar effects in both populations are exhibited by having sisters and brothers. Whereas sisters of reproductive females were associated with higher mortality[2], brothers were associated with decreased mortality. Siblings of the same gender face a harsh competition for family's resources (Fox et al. 2016; Beise & Voland 2008), whereas siblings of the opposite gender do not and might rather be source of support. A further similarity is to be found in the absence of distinct negative consequences of living with the in-law lineage; and in both populations, there is evidence that the mother-in-law is associated with reduced mortality. Willführ et al. (2018) suppose that consanguinity "solved" at least to some extent the genetic in-law conflict.

Unfortunately, we can only speculate on the economic situation of the families-in-law in the St. Lawrence since data on SES are not available. However, it appears unlikely that people in the earlier period of the colony in the St. Lawrence Valley would have intermarried in order to concentrate wealth. Families could much easier increase their land property by clearing forest and therefore intermarriage could have been much less attractive when compared to the Krummhörn region. However, Caron and

---

[2] Please note that the negative effect of having sisters in both populations is only observed in the family fixed-effect models.

Dillon, (2013) describe the practice of ‘exchange marriages’ (, p. 14) where sets of brothers and sisters where married to each other. This system tied relationships between families which could be interpreted as form of inter-family alliance building. Especially among patrilocal societies where the daughters cannot easily rely on support of their natal family this could act as a reciprocal insurance system to protect the daughter from economic exploitation in the household of in-law family. Further studies will be conducted in order to test the explanatory power of this hypothesis and to assess the question whether the positive mother-in-law effect in both populations is due to different reasons.

Another explanation why reproductive women did well if they lived with husband’s kin is to be found in a selection scenario of more vital and less vulnerable women. This hypothesis is not mutually exclusive to the aforementioned hypotheses. Women who married into wealthy or well established families might have been selected in regard to certain personal characteristics that might have been associated with lower mortality. Because of the shortage of women, especially in the early period of the colony, females in the St. Lawrence Valley could have been very particular on the matrimonial market. In this perspective, the positive effect of the in-law family is not caused by their support or by opening up new opportunities, but due to assortment (cf. phenotypic correlation). As a side note, it is worth mentioning that research on the origins of inequality faces the same problem. Biological and socioeconomic factors form a mélange of effects that are hard to disentangle (Van Lenthe 2004).

A striking difference between the St. Lawrence Valley and the Krummhörn region, however, is the role of spatial proximity in regard to kin effects at the individual as well as on the lineage level. Whereas many kin effects in the Krummhörn region appear to be dependent on spatial proximity, kin effects which are linked to close spatial distance were rare in the St. Lawrence Valley. The only exceptions are the aforementioned, positive effect of the biological mother and the effects of the sisters-in-law and of the sisters of the mother-in-law. We interpreted this as a reflection of environmental context differentials. In the Krummhörn region people - especially among the fraction of the landless - faced difficulties to start their own households. In fact, the demographical saturated conditions in combination with the comparably low mortality rates caused a permanent net-migration out of the Krummhörn region. Living in close spatial proximity to in-law or natal family members is therefore a proxy of families' economic establishment in the region. In contrast to the Krummhorn region, the population of the St. Lawrence Valley was expanding. Couples who established their place of residence closely to wife's or husband's family were not necessarily socially successful or prospering in economic terms. However, an alternative explanation for the absence of spatial kin effects in the St. Lawrence Valley is to be found in the different geographical dimensions. Distances between farms, villages, and other settlements in New France were on average much larger than in the Old World and living in the same parish might not indicate the same spatial proximity or contact in daily life as in the Krummhörn region. For instance, the distance between Quebec City and Montreal is roughly ten times larger than the diameter of the Krummhörn region.

In sum, mortality differentials of reproductive females in both populations existed and were connected to the compositions of the kin network. There were interpopulational differentials in kin effects, which could be interpreted as a reflection of the population-specific socio-economic context. However, there were also some remarkable similarities especially in regard to effects of kin belonging to the natal core family and to the in-law family. Our findings do not support the assumption that a woman's natal kin represented a source of unconditional support and that her in-law kin represented a source of unconditional competition.

References

Allison PD. Event history and survival analysis. Thousand oaks, CA: Sage; 2014.

Allison PD. Fixed effects regression models. Thousand oaks, CA: Sage; 2009.

Amorevieta-Gentil, M. (2009. *Les niveaux et les facteurs déterminants de la mortalité infantile en Nouvelle-France et au début du Régime Anglais (1621-1779)*. (Unpublished doctoral dissertation). Université de Montréal, Montréal

Bates, R. (1986). Les conceptions prénuptiales dans la vallée du Saint-Laurent avant 1725. *Revue d'histoire de l'Amérique française*, 40(2), 253-272.

Beise, J. (2005). The helping and helpful grandmother: The Role of maternal and paternal grandmothers in child mortality in the seventeenth and eighteenth century population of French settlers in Quebec, Canada. In E. Voland and Anthanasior Chasiotis (Eds.) *Grandmotherhood: The Evolutionary Significance of the Second Half of Female Life* (pp. 215-238). Piscataway, NJ: Rutgers University Press.

Beise, J. and Voland, E. (2008). Intrafamilial resource competition and mate competition shaped social-group-specific-natal dispersal in the 18th and 19th century Krummhörn population. *American Journal of Human Biology, 20*, 325-336.

Bouchard, G. (2000). La sexualité comme pratique et rapport social chez les couples paysans du Saguenay (1860-1930). *Revue d'histoire de l'Amérique française*, 54, 183-217.

Boudreau, C., Courville, S., and Séguin, N. (1997). Atlas historique du Québec: Le territoire. Sainte-Foy: Les Presses de l'Université Laval.

Caron, M. and Dillon, L. (2013). Exchange marriages between sibsets: A sibling connection beyond marriage, Québec 1660-1760," Paper presented at the IUSSP International Conference, Busan, South Korea.

Charbonneau, H., Desjardins B., Légaré, J., and Denis, H. (2000). The population of the St. Lawrence Valley, 1608-1760. In M. Haines & R. Steckel (Eds.) *A population history of North America* (pp. 99-142). Cambridge, UK: Cambridge University Press.

Charbonneau, H., and Légaré, J. (1967). La population du Québec aux recensements de 1666 et 1667. Population, 6, 1031-1054.

Cliche, M.A. (1988). Filles-mères, familles et société sous le Régime français. *Histoire sociale/Social History*, 21(41), 39-69.

Cox D Regression models and life tables. Journal of the Royal Statistical Society B. 1972; 34: 187–20.

Danielsbacka M, Tanskanen AO, Jokela M, Rotkirch A. (2011) Grandparental child care in Europe: Evidence for preferential investment in more certain kin. Evolutionary Psychology, 9, 3-24.

Dillon, L., Gentil-Amorevieta, M., Caron, M., Lewis, C., Guay-Giroux, A., Desjardins, B., Gagnon, A., (2015). The Registre de la population du Quebec ancien: Past, Present and Future Developments in a Family Reconstitution Database. Manuscript submitted for publication.

Dillon, L. (2010). Parental and sibling Influences on the timing of marriage, 17th and 18th-century Quebec. *Annales de démographie historique*, 1(119), 139-180.

Euler HA, Weitzel B. (1996) Discriminative grandparental solicitude as reproductive strategy. Human Nature.; 7: 39-59

Gagnon A., Heyer E. (2001). Intergenerational correlation of effective family size in early Quebec 1608-1800. *American Journal of Human Biology*, 13(5), 645–659.

Gagnon A., Toupance B., Tremblay M., Beise J., Heyer E. (2006). Transmission of migration propensity increases genetic divergence between populations. *American Journal of Physical Anthropology*, 129, 630–636.

Gibson, M.A. and Gurmu E. (2011). Land inheritance establishes sibling competition for marriage and reproduction in rural Ethiopia. PNAS, 108(6), 2200–2204.

Gaulin SJC, McBurney DH, Brakeman-Wartell SL. (1997) Matrilateral biases in the investment of aunts and uncles: A consequence and measure of paternity uncertainty. Human Nature.; 8: 139-151.

Hagen, E.H. and Barret H.C. (2009). Cooperative breeding and adolescent siblings: Evidence for the ecological constraints model? Current Anthropology, 50, 727-737.

Hamilton WD (1964) The genetical evolution of social behaviour. J.Theoret.Biol.7:1-16

Johow J, Willführ KP, Voland E (submitted) High consanguinity promotes intergenerational wealth concentration in socioeconomically privileged Krummhörn families of the 18th and 19th centuries

Kok, J. (2007). Principles and prospects of the life course paradigm. Annales de démographie historique, 1(113), 203-230.

Kramer K. L. (2005) Children's Help and the Pace of Reproduction: Cooperative Breeding in Humans. Evolutionary Anthropology 14(6), 224-237.

Laberge, A., Gouger, L., and Boisvert, M. (1996). L’expansion de l’écoumène. In S. Courville (Ed.) *Atlas historique du Québec: Population et territoire* (pp. 58-59). Sainte-Foy: Les Presses de l’Université Laval.

Laberge, A. and Mathieu, J. (1996). L’expansion de l’écoumène. In S. Courville (Ed.) *Atlas historique du Québec: Population et territoire* (pp. 45-54). Sainte-Foy: Les Presses de l’Université Laval.

Nitsch, A., Faurie, C., and Lummaa V. (2014) Alloparenting in humans: fitness consequences of aunts and uncles on survival in historical Finland. *Behavioral Ecology*, 25(2), 424–433.

Ohling, G. D. (1963). Kulturgeschichte des Krummhörn. In J. Siele & G.D. Ohling (Eds.) *Die Acht und Ihre Sieben* (pp. 17-288). Pewsum: Erster Entw/isserungsverband Emden.

Rutstein SO Infant and child mortality: levels, trends and demographic differentials. Revised edition. Voorburg, the Netherlands: International Statistical Institute. 1984.

Sear, R., Mace, R. (2008) Who keeps children alive? A review of the effects of kin on child surivial. Evolution and Human Behavior 29:1-18

Steelman, L. C., Powell B. Werum, R., and Carter, S. (2002). Reconsidering the effects of sibling configuration. *Annual Review of Sociology,* 28, 243-269.

Suanet B., Bras H. (2014). Sibling Position and Marriage Timing in the Netherlands, 1840-1922: A Comparison across Social Classes, Local Contexts, and Time. *Journal of Family History*, 39(2), 126-139.

Van Lenthe FJ, Schrijvers CTM, Droomers M, Joung IMA, Louwman MJ, Mackenbach J. (2004) Investigating explanations of socio-economic inequalities in health. The European Journal of Public Health, 14(1): 63-70.

Voland, E. and Beise, J. (2005). The husband's mother is the devil in the house. In E. Voland and Anthanasior Chasiotis (Eds.) Grandmotherhood: The Evolutionary Significance of the Second Half of Female *Life* (pp. 239-255). Piscataway, NJ: Rutgers University Press.

Voland, E. and Dunbar, R.I.M. (1995). Resource competition and reproduction: The relationship between economic and parental strategies in the Krummhörn population (1720-1874). *Human Nature,* 6(1), 33-49.

Voland, E. (2000). Longevity and the costs of reproduction in a historical human population. *Proceedings of the Royal Society of London,* 267, 31-35.

Willführ, K. and Gagnon, A. (2012). Are stepmothers evil or simply unskilled? Infant death clustering in recomposed families. *Biodemography and Social Biology,* 58, 149-161.

Willführ, K. and Gagnon, A. (2013). Are stepparents always evil? Parental death, remarriage, and child survival in demographically saturated Krummhörn (1720-1859) and expanding Quebec (1670-1750). *Biodemography* and Social Biology, 59, 191-211.

Willführ KP, Johow J, Voland E (2018) When the mother-in-law is just as good—Differential mortality of reproductive females by family network composition. *PLoS ONE* 13(3):e0193252. doi:10.1371/journal.pone.0193252

Willführ, K. and Myrskylä, M. (2013). Phenotype-environment mismatch due to epigenetic inheritance? Programming the offspring's epigenome and the consequences of migration. *American Journal of Human Biology,* 25, 318-328.

Willführ, K. and Myrskylä, M. (2014). Disease load at conception predicts survival in later epidemics in a historical French-Canadian cohort, suggesting functional trans-generational effects in humans. *PLOS One,* 9(4), e93868.

Willführ, K. and Störmer, C. (2015). Social Strata Differentials in Reproductive Behavior among Agricultural Families in the Krummhörn Region (East Frisia, 1720-1874). Life Course Studies, 2, 58-85.

Table 1 - Descriptive statistics: Number of cases and failures, and mean ages at important events.

N girls born to marriages contracted between 1670 and 1730	**35,618**
N cases deleted because of unknown birth and dates	-4,287
N cases deleted because of ID was not born in the colony	-2,571
N cases deleted because ID never married or the date of marriage is unknown	-11,911
N cases deleted due to missing other characteristics	-350
N cases remaining in the sample	**16,499**
Born to N families	6,861
N died before reaching age 45	4,629
N died within a postpartum period	1,075
1st birth related	170
2nd birth related	116
3rd birth related	87
4th and higher birth orders	702
Mean age at death of IDs who died before reaching age 45 (standard deviation)	33.45 (±7.24)
N censored before reaching age 45	1,578
Consanguinity	
Consanguineous marriages up to great-grandparents	
from father's lineage related to husband's father's lineage	28
from mother's lineage related to husband's father's lineage	37
from husband's father's lineage related to husband's mother's lineage	36
from husband's mother's lineage related to husband's mother's lineage	26
Marriages of first degree cousins	
paternal parallel cousins (father's brother is husband's father)	10
maternal parallel cousins (mother's sister is husband's mother)	5
paternal cross cousins (father's sister is husband's mother)	11
maternal cross cousins (mother's brother is husband's father)	12
Exchange marriages	
At least one sibling (same mother) has the same mother-in-law	2,280 (13.8%)

At least one sibling (same mother) has the same father-in-law	2,293 (13.9%)
At least one sibling (same mother) has the same parents-in-law	2,229 (13.5%)
At least one sibling (same mother) has the same mother-in-law	2,314 (14.0%)
At least one sibling (same mother) has the same father-in-law	2,329 (14.1%)
At least one sibling (same mother) has the same parents-in-law	2,265 (13.7%)
Total N episodes (on average per ID)	1,450,293 (87,90)
Mean age at first marriage [= mean age at entry] (standard deviation)	23.53 (±5.63)
Mean age at exit (standard deviation)	36.54 (±10.86)
Birth cohort*	
1670-9	142
1680-9	721
1690-9	1,057
1700-9	2,236
1710-9	2,315
1720-9	3,671
1730-9	3,677
1740-9	2,371
1750-9	305
1760-9	4
Birth order (1=first born)	
1	2,062
2	1,957
3	1,817
4	1,669
5	1,630
6	1,395
7	1,286
8	1,119
9	1,013
10	815
11	613

12	445
13	285
14	171
15	108
16	61
17	31
18	8
19	12
20	1
21	0
22	1

* - as used in the models

Table 2 – Results of the Cox regression estimating the impact of the absolute size of the lineages on the mortality of reproductive women. Hazard ratios are presented together with indicators of statistical significance (*** p<0.001, ** p<0.01, * p<0.05, + p<0.1).

	Spatial[1]		**Alive**[2]	
	Clustered[3]	**Fixed-effect**[4]	**Clustered**[3]	**Fixed-effect**[4]
Mother	0.863*	0.654+	0.912**	0.726**
Father	1.078	0.975	1.014	0.782*
Sisters	0.997	1.214	0.974**	5.653***
Brothers	0.993	0.881	0.991	0.746***
Maternal aunts	0.985	0.997	0.976*	0.755***
Paternal aunts	1.006	1.037	1.006	0.914
Maternal uncles	0.987	0.951	1.022	0.865*
Paternal uncles	1.008	1.107	0.998	0.925
N daughters alive	0.861***	0.863***	0.863***	0.876***
N sons alive	0.869***	0.890***	0.872***	0.884***
N female births	1.113***	1.117***	1.112***	1.106***
N male births	1.099***	1.093***	1.098***	1.106***
Postpartum period	3.061***	2.987***	3.031***	3.066***
Husband alive	0.713***	0.737***	0.716***	0.768***
Birth order [1=first born]	0.998	1.000	1.002	1.000
Birth cohort	1.001	1.000	1.001	1.081***
N women	16,499	14,171	16,499	14,171
Dead	4,629	3,904	4,629	3,904
N families (cluster and strata, respectively)	6,861	4,533	6,861	4,533
Observations	1,450,293	1,450,293	1,450,293	1,450,293
Likelihood ratio test	1088	444.1	1108	1741

[1] – dummies only consider living kin who were residing in the same parish as the ID
[2] – dummies consider all living kin regardless their place of residence
[3] – each individual is compared to all other reproductive women in the sample
[4] – each individual is compared to her reproductive sisters

Table 3 – Results of the Cox regression estimating the impact of the absolute size of the lineages on the mortality of reproductive women. Hazard ratios are presented together with indicators of statistical significance (*** p<0.001, ** p<0.01, * p<0.05, + p<0.1).

	Spatial[1]		**Alive**[2]	
	Clustered[3]	**Fixed-effect**[4]	**Clustered**[3]	**Fixed-effect**[4]
mother-in-law	1.041	0.959	0.965	0.887*
father-in-law	0.874	0.618	0.992	0.886+
sisters-in-law	0.994	0.963+	1.015	1.020
brothers-in-law	0.998	1.031	1.018	1.027
sisters of mother-in-law	0.970	0.935*	0.991	0.998
sisters of father-in-law	1.017	1.030	0.991	1.016
brothers of mother-in-law	0.978	1.010	0.996	0.972
brothers of father-in-law	0.979	0.984	1.012	1.019
N daughters alive	0.857***	0.863***	0.854***	0.859***
N sons alive	0.867***	0.870***	0.865***	0.866***
N female births	1.113***	1.121***	1.114***	1.123***
N male births	1.103***	1.117***	1.103***	1.120***
Postpartum period	3.056***	3.012***	3.097***	3.026***
Birth order [1=first born]	1.001	1.005	1.000	1.006
Birth cohort	1.000	0.992*	1.000	0.993
N women	13,207	10,686	13,207	10,686
Dead	3,593	2,892	3,593	2,892
N families (cluster and strata, respectively)	6,227	3,706	6,227	3,706
Observations	1,141,468	957,184	1,141,468	957,184
Likelihood ratio test	827.5	296.1	828	297.1

[1] – dummies only consider living kin who were residing in the same parish as the ID

[2] – dummies consider all living kin regardless their place of residence

[3] – each individual is compared to all other reproductive women in the sample

[4] – each individual is compared to her reproductive sisters

Table 4 – Results of the Cox regression estimating the impact of the absolute size of the lineages on the mortality of reproductive women. Hazard ratios are presented together with indicators of statistical significance (*** p<0.001, ** p<0.01, * p<0.05, + p<0.1).

	Spatial[1]				**Alive**[2]			
	Unweighted (simple count)		**Weighted** (numbers are weighted with coefficient of relatedness)		**Unweighted** (simple count)		**Weighted** (numbers are weighted with coefficient of relatedness)	
	Cluster-ed[3]	**Fixed-effect**[4]	**Cluster-ed**[3]	**Fixed-effect**[4]	**Cluster-ed**[3]	**Fixed-effect**[4]	**Cluster-ed**[3]	**Fixed-effect**[4]
Natal family	0.994	1.019	0.986	1.048	0.993+	1.211***	0.979+	1.992***
In-law family	0.992	0.990	0.985	0.978	1.005	0.999	1.016+	0.996
N daughters alive	0.857	0.864***	0.857	0.864	0.856***	0.869***	0.856	0.870***
N sons alive	0.868	0.869***	0.868	0.869	0.867***	0.861***	0.867	0.857***
N female births	1.113	1.119***	1.113	1.118	1.114***	1.118***	1.114	1.115***
N male births	1.102	1.117***	1.102	1.117	1.103***	1.127***	1.102	1.131***
Postpartum period	3.047	2.996***	3.050	2.997	3.067***	2.963***	3.071	2.978***
Birth order [1=first born]	1.001	1.005	1.001	1.005	1.003	1.005	1.003	1.004
Birth cohort	1.000	0.995	1.000	0.995	1.000	1.042***	1.000	1.061***
N women	13,207	10,686	13,207	10,686	13,207	10,686	13,207	10,686
Dead	3,593	2,892	3,593	2,892	3,593	2,892	3,593	2,892
N families (cluster and strata, respectively)	6,227	3,706	6,227	3,706	6,227	3,706	6,227	3,706
Observations	1,141,468	957,184	1,141,468	957,184	1,141,468	957,184	1,141,468	957,184
Likelihood ratio test	826	287,5	824.8	287.4	825.5	401.7	827.5	491

[1] – dummies only consider living kin who were residing in the same parish as the ID

[2] – dummies consider all living kin regardless their place of residence

[3] – each individual is compared to all other reproductive women in the sample

[4] – each individual is compared to her reproductive sisters

Table 5 – Results of the Cox regression estimating the impact of the relative size of the lineages on the mortality of reproductive women. Hazard ratios are presented together with indicators of statistical significance (*** p<0.001, ** p<0.01, * p<0.05, + p<0.1).

	Spatial[1]			
	Unweighted (simple count)		**Weighted** (numbers are weighted with coefficient of relatedness)	
	Clustered[2]	**Fixed-effect**[3]	**Clustered**[2]	**Fixed-effect**[3]
Relative sizes of lineages (Ref. natal lineage only)				
Natal lineage was larger	1.027	1.043	1.024	1.092
Lineages were equal in size	1.012	0.837	1.002	0.796*
In-law lineage was larger	0.977	0.881	0.990	0.860+
In-law lineage only	0.928	0.824	0.927	0.804+
N daughters alive	0.856***	0.863***	0.856***	0.863
N sons alive	0.867***	0.869***	0.867***	0.869
N female births	1.114***	1.120***	1.114***	1.119
N male births	1.103***	1.118***	1.103***	1.118
Postpartum period	3.066***	2.997***	3.068***	3.003
Birth order [1=first born]	1.001	1.006	1.001	1.006
Birth cohort	1.000	0.994	1.000	0.995
N women	13,207	10,686	13,207	10,686
Dead	3,593	2,892	3,593	2,892
N families (cluster and strata, respectively)	6,227	3,706	6,227	3,706
Observations	1,141,468	957,184	1,141,468	957,184
Likelihood ratio test	82.5	286.4	822.3	296.2

[1] – dummies only consider living kin who were residing in the same parish as the ID

[2] – each individual is compared to all other reproductive women in the sample

[3] – each individual is compared to her reproductive sisters