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Overcoming Methodological Challenges in Evolutionary Psychological Research on Differential Grandparental Kin Investment

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Affidavit

I hereby confirm that my thesis is the result of my own work. I did not receive any help or support from commercial consultants. All sources and / or materials applied are listed and specified in the thesis.

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Vienna, December 4, 2013

Contents

Introduction

In recent years, there has been an increase in research on differential grandparental kin investment (DGKI) in the field of grandparenthood; for a brief outline on grandparenthood see Szinovacz (1998). Several studies concerning the unequal distributions of grandparental investment towards grandchildren have been published in the past twenty-five years with Harald A. Euler and Barbara Weitzel being the most prominent (1996). However, research results have not always been consistent. With critique on the adequacy of methods and questions about inconsistent findings the necessity to further investigate and clarify the nature of discriminative kin investment is raised.

Daly and Wilson (1980) provided an evolutionary explanation for discriminative parental solicitude on a complementary basis to the social sciences views. Euler and Weitzel (1996) widened the field of research analyzing DGKI under the same light. Both authors questioned the explanation power of social engendered roles ascribed to women, as it could not explain their findings, impacting subsequent researchers to focus more on evolutionary explanations.

An evolutionary framework has been consolidating over time as several concepts interconnect (see Chapter. 3.2). Paternity uncertainty and sex-specific reproductive strategies are dominant in predicting and explaining the alleged differences of grandparental solicitude. Still, deviating findings were published. Although such an evolutionary framework does not exist in form of an integrated theory yet, there is not much room for other contemplations. With few exceptions (e.g., Pashos, 2000), social scientific explanations vanished in this area of research leaving no alternative explanation.

Recently, Tran, Fisher, and Voracek (2009) pointed out that exposure to grandparents (for details see Exposure) follows the same order as sex- and lineage-effects found by Euler and Weitzel (1996). Demographic differences like grandfather's and grandmother's age at marriage as well as age at death add up, which were found to account at least partially for some of the differences. They proposed that previous found sex- and lineage-effects need to be reinvestigated and following research should take this into account.

Various authors used different methods to investigate this phenomenon. So far, however, there has been little discussion about a general definition of DGKI and with no compromised operationalization in hand conflicting findings will continue to be published. The use of different operationalizations make it difficult to compare results from different research teams. Also, two main approaches were frequently used to gather information on DGKI - by either asking grandchildren or grandparents - which bring different advantages and problems with them. It is advantageous to look at a problem from different perspectives, but it might be even more beneficial combining these different perspectives.

Some statistical methods of data analysis that were previously used are rather questionable and do not seem suited for an appropriated evaluation of this matter. Most scientists used a General Linear Model (GLM) approach which handles correlated dependent and repeatedly measured data in an erroneous way, especially when cross-level interactions are observed. More appropriate methods may have provided different findings.

This diploma thesis attempts to illuminate contradictions of previous investigations and aims to provide a refined approach incorporating most relevant aspects. For this purpose the thesis, at first, deals with basic and more specific social, evolutionary and psychological theories centered around predicting and explaining DGKI. Findings from previous works are incorporated as well as the different survey designs, operationalizations and analytic methods utilized, which are then analyzed, contrasted and discussed. In the second part of this thesis, conclusions drawn from the first part are then used to formulate the research objective upon which an empirical research is carried out. The corresponding survey design, the statistical methods and the results are then reported, discussed and compared with previous findings.

Part I.

BACKGROUND

The theoretical background is divided into four chapters. The first chapter begins with a short introduction to evolutionary psychology. The second chapter provides three general evolutionary concepts relevant for grandparental kin investment. In the third chapter, grandparental kin investment is depicted in detail which starts by laying out a broader definition of kin investment which is then applied to grandparental kin investment. In the following sections of the same chapter relevant theories predicting and explaining differential grandparental kin investment are introduced and important influential factors are described. Findings from previous works are incorporated in this chapter as well. In the last chapter, previous scientific works on differential grandparent kin investment are analyzed and compared upon multiple methodical aspects.

1. Evolutionary Psychology

Evolutionary psychology is a comparatively new approach in psychology. The integration of evolutionary principles with psychological mechanisms can help understand the existence of such mechanisms. This way, the variety of human behaviors (as well as cognitions) are seen as adaptations to problems human ancestors had to adjust to. Evolutionary psychology explores the ultimate causal processes that are underlying those evolved psychological adaptations; adaptations that developed through the same mechanisms of natural selection (see Chapter 2) creating an enormous biodiversity.

Concepts of evolutionary psychology are already applied to a multitude of psychological topics, like mating, altruism, gender differences, social behavior in groups and parenthood. Evolutionary psychologists try to identify and analyze problems human progenitors had to overcome and they describe the impact of acquired adaptations on modern times. While some adaptations for hominids had fitness advantages in the past, especially for homo sapiens, they might not have an adaptive and hence fitness enhancing function nowadays, although still present. For example, it is supposed that grandparenting in times with high child mortality rates had a positive effect on the survival of children by providing a broad range of solicitude like childcare, food and education. In societies with low child mortality rates and increasing social childcare services grandparenting becomes more obsolete (Ghysels, 2011), but will be practiced nevertheless. Understanding and integrating evolutionary processes helps to understand and explain current behaviors more clearly.

2. Concepts of Evolution

2.1. Natural Selection

The most fundamental evolutionary concept is that of natural selection which Charles Darwin (1859) described as the central tenet of evolution. Darwin's well accepted concept of evolution consists of three mechanisms - variation, selection and heredity - which determine the evolutionary wheel of constant change. These three mechanisms are not only responsible for the exitance of man kind in general, but for all of human behaviors including the provision of investment.

Variations of morphological as well as psychological characteristics mainly arise from mutations in the parental generation, who are in general not effected by these alterations. Genetic modifications caused by various kinds of radiation, like solar radiation, are then passed on to the next generation. In the offspring generation such modification might be expressed as changes in behavior or appearance. In general, mutations can be positive, negative or have no effect on reproductive fitness.

Charles Darwin pointed out an easy to obtain but important fact, namely, that in general more offspring are produced then will survive before they reach reproductive phase. But, survival alone does not guarantee genetic success as an individual has to find a proper mate to reproduce with as well. Consequently, the existence of survival and sexual pressure allows for selection to occur. Out of *too* many individuals only those individuals will survive and reproduce who have fitness advantages over other rivals. By fulfilling environmental requirements and adapting to ecological changes individuals are selected to bequeath their genes to the next generation.

From the perspective of individuals the main objective seems to be maximizing fitness in terms of producing more successfully surviving descendants than others. Another way of looking at fitness is the gene's point of view which assumes that fitness maximization happens at the gene level. Accordingly, genes strive to maximize the production and promotion of copies of themself.

2.2. Inclusive Fitness and Kin-Selection

William D. Hamilton extended the classical view of fitness by discovering that "a gene causing its possessor to give parental care will then leave more replica genes in the next generation than an allele having the opposite tendency" (1964, p. 1). It is well accepted that such altruistic genes have in fact evolved. This means that with the degree of relatedness, representing the chance of sharing altruistic genes, investment in close relatives can maximize ones own fitness, indirectly. The amount of investment provided to a specific relative, however, depends not only on the genetic relatedness but also on the expected benefits according to Hamilton's rule $r * B > C$. Therefore, for an altruistic act to be fitness enhancing, the benefit B multiplied by the genetic relatedness r must be larger than the costs C to invest in relatives; common degrees of relatedness are .5 for sibling-sibling and parent-children relatives, .25 for grandparent-grandchildren and aunt/uncle-niece/nephew relatives and .125 for cousin-cousin relatives. Hamilton's rule can easily be applied to grandparental kin investment as well. On this account, grandparents should select blood-related grandchildren over adopted grandchildren when investing resources or when it comes to affection (Mansson & Booth-Butterfield, 2011).

2.3. Reproductive Value

Another interesting evolutionary concept affecting kin investment is the reproductive value which goes back to Fisher (1930). Reproductive value of an individual describes the potential of fertility for the production of offspring which changes over time. The characteristic trend of reproductive value is connected with the age of an individual and also differs among the sexes. Figure 1 illustrates the course of change over the lifespan for both sexes. It can be seen that the onset of reproductive value starts with puberty and increases more rapidly for women than for man. The reproductive potential then peaks at different gender-specific ages. Afterwards, reproductive value decreases faster for women than for men.

The different gradients of reproductive value are important on at least two levels. First, after the reproductive peak independent of the individuals gender, it becomes more favorable to invest in relatives in order to keep maximizing fitness. After the age of

40, however, the reproductive value is larger for men than for women, hence it becomes more likely that women will use more indirect fitness enhancement strategies. In the end, it will be the only option for women when their fertility stops after menopause, while some of the reproductive potential remains for men. On the second level, this means that investment also depends on the reproductive value of offspring and therefore on their age and gender. When dividing limited resources among offspring it will be more likely for those grandchildren with higher reproductive value to receive more investment. Still, a grandparent's preference may change over time as the reproductive value of grandchildren and the perceived benefits change too.

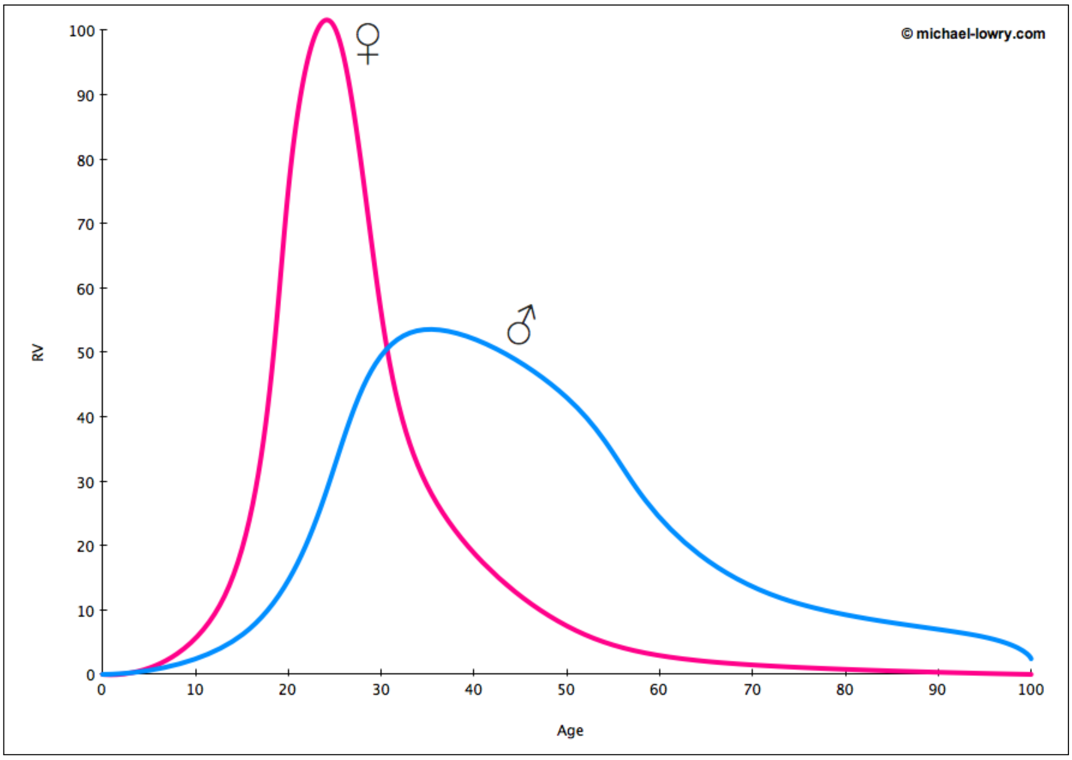


Figure 1: Reproductive value versus age for women (♀) and men (♂). Reprinted from *Reproductive value and the marriage bargain*, by M. Lowry, 2012, Retrieved from `http://blog.michael-lowry.com/2012/05/reproductive-value-and-marriage-bargain.html`, Copyright 2012 by michael-lowry.com.

3. Grandparental Kin Investment

3.1. Defining Grandparental Kin Investment

Before looking at various theories concerning DGKI, grandparental kin investment has to be defined first. The meaning might seem trivial, nevertheless, it has to be defined before operationalization. And while there exist a few hundred papers on grandparental kin investment non of them provide a concrete definition, unfortunately. Yet, some papers referred to Trivers (1972), who did not define grandparental investment, but he defined parental investment. Hence, a definition of grandparental kin investment can be build upon Trivers' definition of parental investment.

Trivers defined parental investment as "any investment by the parent in an individual offspring that increases the offspring's chance of surviving (and hence reproductive success) at the cost of the parent's ability to invest in other offspring" (1972, p. 139). Interestingly, the last part of the definition sounds like a condition, although it is more of a side-effect or a trade-off situation that might not even be the case in some circumstances. Trivers further specified *any investment* by including feeding, providing safety and the metabolic production of the gametes itself. While the production of gametes is true for parents, it is not for grandparents. On the other hand, Trivers excluded efforts of helping with the search for a proper mate as it does not affect survival of the offspring. Although survival of the offspring is just a means for the purpose of reproductive success. This is somewhat conflicting, as helping to find a proper mate also leads to reproductive success and should not necessarily be excluded. Therefore, I propose a slightly modified definition which does not exclude anything and sets altruistic behavior as the motivation behind all actions, on top of it.

> *"Grandparental kin investment is any action performed by a grandparent which profits grandchildren's survival and reproduction directly or indirectly leading to the duplication of shared (altruistic) genes."*

3.2. Differences in Grandparental Kin Investment

Understanding the basic evolutionary principles and having the definition of grandparental kin investment in mind we can now turn to relevant theories predicting and explaining differences in grandparental kin investment. Hence, the following section presents the development of theories concerning differences between specific grandparents in chronological order. Starting out with a social science theory that discusses proximate causes of possible differences with a focus on grandparents' gender. The section continues with some evolutionary concepts that expand the social science view by additionally differentiating grandparents upon their lineage, focusing more on the ultimate causes. Lastly, more recent extensions of these concepts based on genetic considerations are presented which also take the gender of grandchildren into account.

With different views come different theories providing explanatory power which are also discussed in the following. Although predictions of some theories are overlapping, they also provide unique predictions. As most theories are supported by some findings but are also rejected by others, this field of research lacks of an integrated framework that is flexible enough to explain varying investment differences. To fully understand contemporary grandparenting, different scientific views have to be connected.

Women as Kin-Keeper

First, social sciences considered grandparents not as a sole group anymore, but differentiating between grandmothers and grandfathers. According to the sociological life course perspective (Danielsbacka & Tanskanen, 2012), women inherit the role of a kin-keeper and thus are more involved in family relationships than men are. In the light of cooperative breeding hypothesis it makes sense that women, who assist and are assisted more often during pregnancy, inherit such a role. It is said that the job of a kin-keeper is to preserve family traditions, maintain relationships with other family members, pass information on to kin, organize reunions and help other relatives. This sex-effect transforms into grandmothers investing more in their grandchildren than grandfathers.

Alongside the rise of evolutionary perspectives a distinction between grandparents upon the gender of the parental generation was made, as grandchildren do not only have one grandmother and one grandfather in general. Grandchildren typically have two grandparents on the maternal and two grandparents on the paternal side. This additional distinction of grandparents via their lineage results in the determination of four grandparent-sets, namely, maternal grandmothers (MGM), maternal grandfathers (MGF), paternal grandmothers (PGM) and paternal grandfathers (PGF). It was, therefore, assumed that grandparental investment of these four types does not only differ by their sex but also by their lineage. Regarding the general sex-effect of grandparents - comparing both grandmothers with both grandfathers - grandmothers are often reported to invest more in grandchildren than grandfathers (e.g., Euler & Weitzel, 1996; Silverstein & Long, 1998; Uhlenberg & Hammill, 1998; Salmon, 1999; Pashos, 2000; McBurney, Simon, Gaulin, & Geliebter, 2002). The lineage-effect, on the other hand, states differences between grandparents related through the mother or the father of the grandchildren. It was also reported that maternal grandparents invest more in grandchildren than paternal grandparents (Euler & Weitzel, 1996; Uhlenberg & Hammill, 1998; Salmon, 1999; Pollet, Nelissen, & Nettle, 2009; McBurney et al., 2002) with at least on big exception (Pashos, 2000). The order of rank of these four grandparent-sets was frequently discussed in the last 30 years. The main focus, however, rested on two evolutionary theories. Paternity uncertainty theory and sex-specific reproduction theories were frequently used to predict and explain differences between the four types of grandparents.

Paternity Uncertainty

Paternity uncertainty theory states that due to internal fertilization women are 100% assured that their children are their biological offspring, whereas men can not be completely certain about being the biological father of their offspring due to the possibility of a mates infidelity (Trivers, 1972). And, because there two reproduction cycles between grandparents and grandchildren, there are two links of possible uncertainty for grandparents, as they accumulate. MGM, on the one side, have two certain links and can therefore be 100% certain that the children of their daughters respectively their grandchildren are biologically descended. PGF, on the other end, are least certain whether their sons nor the children of their sons, namely, their grandchildren are biological descended as there are two links of uncertainty. PGM and MGF with only one link of uncertainty, therefore, lie in between which, however, can not be differentiated by this theory.

As the question, how men access paternity certainty, was raised, it was hypothesized that men might make use of different cues to determine paternity uncertainty. Still, as Voracek, Fisher, and Shackelford (2009) argued, men might not always be able to detect women's infidelity as women also have evolved abilities to hide their infidelity. However, Wilson and Daly (1992), for example, proposed that men's perceived facial resemblance between them and their offspring might be an indicator for paternity certainty. Apicella and Marlowe (2004) later reported that men's perception of phenotypic resemblance with their offspring as well as the perceived fidelity of their mates predicted a men's parental investment which was assumed by the authors to indicate paternity certainty. Furthermore, Dubas, Heijkoop, and van Aken (2009) found that fathers showed more emotional closeness towards children whose smell they could identify, and the authors, therefore, proposed that olfactory recognition, as well, might be an indicator for paternity certainty. However, actual genetic relatedness was not accessed in any of these studies. Still, the assumption remains that natural selection has not only favored men with particular abilities to detect women's infidelity and thus potential cuckoo children, but also those men counteracting such incertitude, for example, by investing less in potential cuckoo children.

Sex-specific Reproduction Strategies

Because Euler and Weitzel (1996) found that MGF were investing more than PGM, another evolutionary theory was incorporated to explain these findings. According to the theory of sex-specific reproduction women focus more on the production of high-quality egg cells, thus, gaining fitness advantages by more intense parental investment. Opposingly, men increase their reproductive fitness by engaging in extra-pair copulations. On this account, the amount of parental investment also depends on the sex of an offspring. Investment into female descendants will likely be greater as they have to invest more in their kin later on. Findings across different disciplines and societies support this female kin bias (Coall & Hertwig, 2010). Additionally, investment in daughters and sons will concern different aspects since both genders have different ways to maximize their reproductive success. That is, parental investment into sons will focus more on mating aspects unlike the investment into daughters which will concentrate more on parental support. It follows, because PGM invest in sons' offspring and MGF invest in daughters' offspring, that MGF will invest more than PGM.

Preferential Investment

Laham, Gonsalkorale, and von Hippel (2005) proposed a different theory with similar predictions for MGF and PGM under specific circumstances. The preferential investment theory states that investment of MGF only exceeds that of PGM if PGM have additional grandchildren through daughters, into who they can invest. This theory does not match with the data obtained by Bishop, Meyer, Schmidt, and Gray (2009), whereas it gains support from Danielsbacka, Tanskanen, Jokela, and Rotkirch (2011).

Nevertheless, Euler and Weitzel (1996) explained their findings by combining paternity uncertainty theory with sex-specific reproduction theory. Interestingly, sex-specific reproduction theory alone provides the same predictions, since individuals invest more in female descendants and their children than male descendants and their children; women on top of all invest more than men. Still, reports that found no difference between MGF and PGM (Attar-Schwartz, Tan, & Buchanan, 2009; Bishop et al., 2009) at all or even with a reverse relationship of PGM investing more than MGF (Tran et al., 2009) exist. However, the reported order differences can to some extend be explained by the connection between sex- and lineage-effect. If each type of grandparent is seen as the combination of sex- and lineage-effect, and it is assumed that one or both effects vary in different societies, different orders between MGF and PGM can be acquired.

Sex Chromosomal Selection

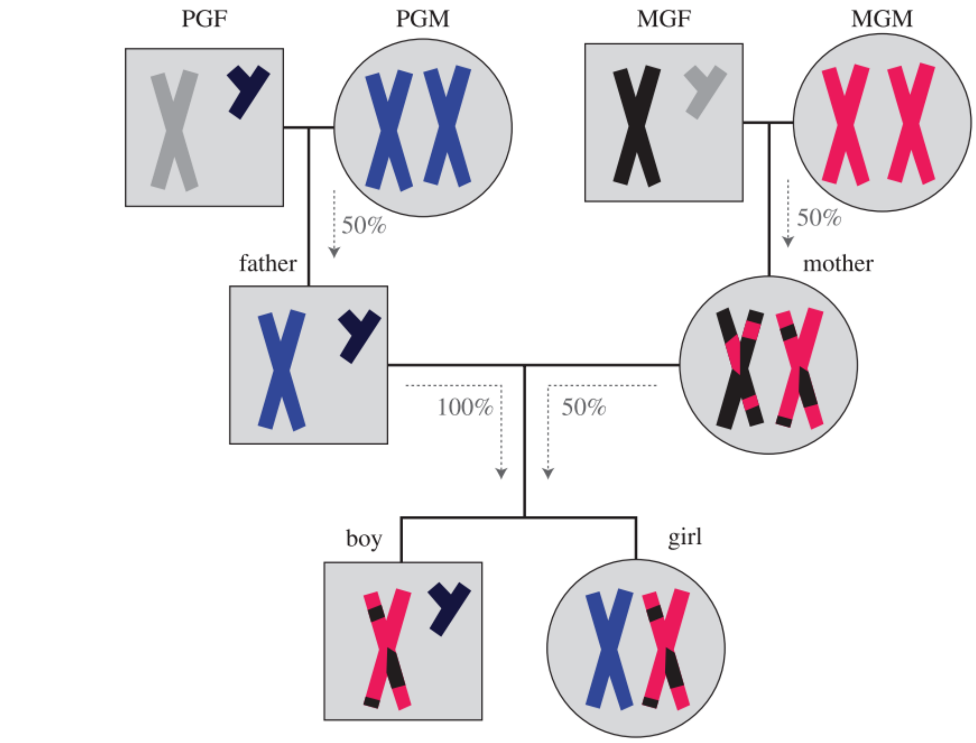
More recent genetic ideas introduced the gender of grandchildren as an additional crucial factor. According to those ideas, investment of some type of grandparents differ with respect to grandsons and granddaughters. The genetically driven sex chromosomal selection theory was introduced by Chrastil, Getz, Euler, and Starks (2006). As pointed out before, grandparents in general are to a fourth related with their grandchildren which is, however, only true for autosomes and not for gonosomes; the two sex-specifying chromosomes are called gonosomes, whereas the other 44 chromosomes are called autosomes. As women have two X chromosomes (homozygous) men are heterozygous with respect to sex-chromosomes, with only one X and one Y chromosome. Therefore, the possibility for genes on the sex-chromosomes to allow for differential preference or altruism towards same-sex grandchildren is given.

PGF share the Y chromosome with grandsons while the PGM do not share a single sex-chromosome with grandsons. On the other hand, PGM share one of her X chromosomes with granddaughters while PGF do not share sex-chromosomes with granddaugters. Chrastil et al. (2006) tested their idea in comparison to paternity uncertainty, but they found no significant difference within PGM favoring granddaughter (GD) over grandson (GS) when looking at the total sample which led them to conclude that paternity uncertainty overrides sex chromosome selection and, therefore, same-sex preferences. Following this argumentation and the possibility that paternity uncertainty rates vary among different societies it is possible that in societies with extremely low paternity uncertainty rates such a sex chromosome selection might be present.

Sexually Antagonistic Zygotic Drive

Subsequently, Rice, Gavrilets, and Friberg (2008) proposed a very similar theory. The theory of sexually antagonistic zygotic drive (SA-ZD) aims to show that sex chromosome selection indeed contributes to differential grandparental investment. The authors assumed that because the X gonosomes contain more genes than the Y gonosome and because there are more X gonosomes than Y gonosomes a selfish-mutation on the X chromosome is more likely. Such a sex linked-mutation can produce sexual genomic conflict that might be expressed as preferential behavior towards relatives who carry the same genes on their chromosome, while it also can produce harmful behavior towards relatives who do not carry the same genes. This is particularly the case when opposite-sex sibling rivalry exist. Such a preferential or harmful trait "can be expressed as an antagonistic green-beard effect that is mediated by epigenetic parental effects, parental investment, and/or interactions among siblings" (Rice et al., 2008, p. 1). Upon this principle, the authors derived that PGM presumably invest more in their granddaughters than their grandsons and will even harm their grandsons. PGM are related to their grandchildren via their sons, who have inherited one of their two X gonosomes which they then bequeath to their daughters but not at all to their sons. Figure 2 accurately depicts this situation.

With child mortality data from Fox et al. (2010), who researched the slightly different topic of post-menopausal longevity of women with respect to the X gonosome relatedness, Rice, Gavrilets, and Friberg (2010) found their theory of SA-ZD supported. The data on seven historic societies indicated that PGM disproportionately increased



% X-relatedness with MGM	25	25
% X-relatedness with PGM	0	50

Figure 2: X-Chromosome relatedness between grandparents and grandchildren. Reprinted from "Grandma plays favourites: X-chromosome relatedness and sex-specific childhood mortality." by M. Fox, R. Sear, J. Beise, G. Ragsdale, E. Voland, E. and L. A. Knapp, 2010, *Proceedings of the Royal Society B*, *277*, p. 569. Copyright 2009 by The Royal Society.

the likelihood of the survival of granddaughters while her presence decreased such likelihood for grandsons. In particular, in six of seven societies PGM increased the survival of granddaughters more than grandsons, in four of seven societies granddaughters survived better with PGM than MGM and in all seven societies grandsons survived better with MGM than PGM.

Data from Johow, Fox, Knapp, and Voland (2011) on interbirth intervals (IBI) from the historic population of Krummhörn also supported this theory. They concluded that IBI in the presence of PGM increased following the birth of a daughter while on the other side IBI decreased following the birth of a son. As IBI are the time span between an individual's birth and that of the following sibling, it follows that the longer IBI are the more investment can be provided for an individual and vice versa. The prior reported findings from Chrastil et al. (2006), according to whom PGM differed in the investment in granddaughters and grandsons, also supports SA-ZD predictions. Strong support also comes from experiments conducted by Friberg, Stewart, and Rice (2011) on the fruit fly Drosophila. The researchers provided empirical support upon which an X-linked mutation causing a female-biased sex-ratio was produced by SA-ZD as opposed to gametic drive. They also concluded that the theoretical prediction of an X-linked son-killer phenotype could also be evolved. On the contrary, Tanskanen, Rotkirch, and Danielsbacka (2011) examined data from the Child Well-Being 2007 survey and found no evidence of contemporary grandparental differences in human developed population as predicted by X-chromosomal relatedness theories.

In addition, Wilder (2010) noted that resulting from different degrees of relatedness regarding autosomes versus gonosomes a genomic conflict might have promoted two different life history strategies for women. While the autosomes would benefit from sexual reproduction till the end of life, the X gonosomes would benefit from an earlier termination of reproduction, e.g. due to menopause. Another interesting point is that incorporating sex chromosomal differences with paternity uncertainty can make a difference for the orders of grandparental kin investment of the eight grandparent-grandchildren dyads. Figure 3 depicts the average degree of relatedness between grandparents and their grandchildren depending on the degree if paternity uncertainty of the population. In populations with higher paternity certainty which is the case in traditional societies, where extra-pair copulation of women is strictly prohibited respectively more controlled, a zygotic drive might therefore be observed while in populations with low paternity certainty such a drive might not be recognizable.

Findings of previous research were not congruent all the time and led the authors to different conclusions regarding the explanatory power of the different theories. The most recent theory of sexually antagonistic zygotic drive, however, was not really implemented in previous survey designs yet. In previous research, where data was collected from the researchers themselves, it was sufficient enough that one grandchildren regardless of his or her gender was participating. Possible opposite-sex siblings were not taken into account so far, as well. Implications from SA-ZD, however, are that the gender of grandchildren and of their siblings make a notable difference for the paternal grandparents. Therefore, one major objective of the subsequent empirical survey will be to include opposite-sex siblings in order to test the specific predictions derived from sexually antagonistic zygotic drive theory.

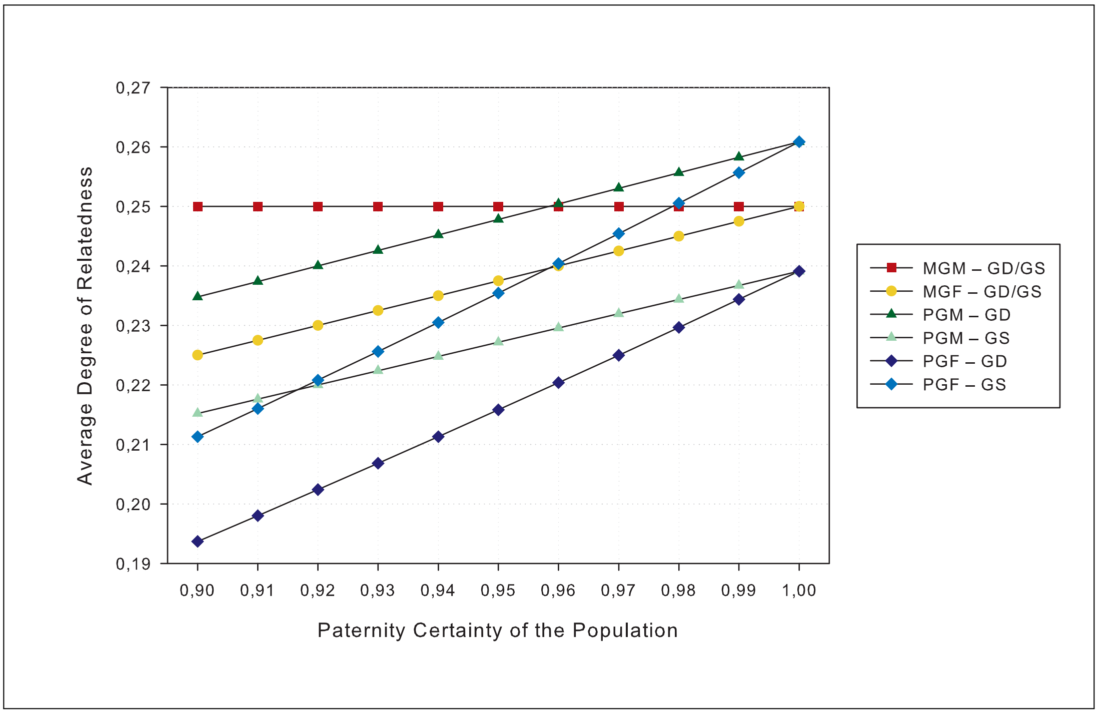


Figure 3: Grandparents degree of relatedness with granddaughters and grandsons depending on the degree of paternity certainty of a population.

3.3. Factors Influencing Grandparental Kin Investment

Grandparental kin investment does not only involve grandparents and grandchildren but also the parental generation in between. With three generations being involved there are many factors that have been identified to influence grandparental kin investment. Most moderators are reported to have a similar effect on all grandparents. However, most studies in the field have not checked for distinct effects of moderators on the different types of grandparents. Possible investment differences between grandparents might be mediated by them in the first place. In the following section all relevant influential factors are presented.

Resemblance

Apicella and Marlowe (2004) reported that the perceived degree of resemblance of men with their children predicted men's investment. Resemblance may serve as a direct cue for men's genetic relatedness with their offspring and hence paternity uncertainty. This might be true for grandparental investment as well and must not be limited to the physical appearance. Still, Euler and Michalski (2007) stated that only Leek and Smith (1991) reported a positive correlation between perceived resemblance with grandchildren and help provided by grandparents and that this connection still lacks direct evidence. It should be noted that when explaining differences with paternity uncertainty theory a measure that represents paternity uncertainty should be included.

Residential Proximity

Residential proximity or the distance between grandparents and grandchildren was reported to have a strong negative effect on investment, at least for face-to-face-contact (Uhlenberg & Hammill, 1998). Most authors assumed that this influence is similar for all grandparents as initial tests from Euler and Weitzel (1996) did not find a significant difference which was also supported by others (e.g., Pollet, Nettle, & Nelissen, 2007). On the contrary, Michalski and Shackelford (2005) reported that in their sample maternal grandparents lived closer to their grandchildren, while Salmon (1999) reported that in her sample paternal grandparents lived closer to their grandchildren which was also supported by Pashos (2000) at least in the rural sample. Residential proximity differences might be subject of a moderation itself, as for example, findings from Pashos (2000) point to a traditional factor involved. Therefore, differences among grandparents regarding proximity should be tested initially or have to be taken into account for each grandparent separately.

Family Size

Another factor which is often found to influence grandparental care, is the family size. The corresponding dilution effect hypothesis states that with increasing number of children and grandchildren the amount of grandparental investment will dilute as limited resources have to be divided. Such a diffusion effect was reported in several studies (Uhlenberg & Hammill, 1998; Fingerman, 2004; Laham et al., 2005; Pollet, Nettle, & Nelissen, 2006; Coall, Meier, Hertwig, Wänke, & Höpflinger, 2009), but was also rejected by at least one more recent study (Danielsbacka & Tanskanen, 2012).

Similarly, the number of grandparents matters. As with a decrease in number of grandparents by reasons of decease, the amount of grandparental investment per remaining grandparent might increase as a compensation (Euler & Weitzel, 1996). Pashos (2000), however, reported no effect of number of grandparents on the average grandparental investment.

Also, the calculation of family size differed among studies. Coall et al. (2009) differentiated between family size of grandparents and that of grandchildren and reported that family size of grandparents explained three times more variance than family size of grandchildren. On the other hand, Uhlenberg and Hammill (1998) used a combined indicator, namely, grandchildren-sets, where the number of grandparents' children who had children themselves are used as an indicator. It still remains in discussion whether the number of grandparents' children or the number of grandchildren are more relevant.

Birth Order

Another relevant factor influencing investment is the birth order. It is assumed that in two-generation families birth order follows a U-shaped trend with first and last born children receiving more parental investment then middle born children. Such an effect, but for grandchildren's birth order, was reported to be of relevance for grandparental investment as well (Salmon, 1999; Coall et al., 2009). Additionally, Salmon (1999) reported that the birth order of the parental generation also followed a U-shaped trend influencing grandparental investment.

Gatekeeper Relationship

Robertson (1975) pointed out that because the parental generation is located between grandparents and grandchildren parents play an important role in grandparental care. According to the *gatekeeper theory* parents moderate the grandparent-grandchildren interaction by increasing or decreasing interactions. Not only does the direct descended relationship influence grandparental investment, but also the in-law relationship of the grandparental with the children in-law (parental generation) (Michalski & Shackelford, 2005) which Fingerman (2004) reported even exceeds that of the direct relationship. Although additional support was provided by some studies (Uhlenberg & Hammill, 1998; Attar-Schwartz et al., 2009) a broader recognition and integration into study designs is still missing.

Marital Status and Co-Residence

Marital status is another relevant parameter for grandparental investment. Divorced grandparents were reported to differ in investment towards their grandchildren, where most reports showed that divorced grandfathers invested less in their grandchildren than non-divorced grandfathers, while no difference for grandmothers was found (Euler & Weitzel, 1996; Uhlenberg & Hammill, 1998; Ghysels, 2011; Pollet et al., 2006; Pashos & McBurney, 2008; Barnett, Scaramella, Neppl, Ontai, & Conger, 2010; Danielsbacka & Tanskanen, 2012). Wood and Liossis (2007). Danielsbacka and Tanskanen (2012) noted that many studies also showed that the martial status of the parents matter for the grandparent-grandchildren relationship, especially for the paternal side. However, most of the previous studies have not collected such data which might be due to the survey condition that parents had to be living together.

The related incidental exposure hypothesis states that grandparental investment of one grandparent influences that of the other grandparent with whom they are living together. And, because not-married grandparents do not necessarily live separated and married couples do not necessarily live together, the specific information of residence might be more appropriate than the marital status itself. It is assumed that co-residing grandparents often pursue family related activities together. It follows that grandparents attending grandparental activities will increase activities of the other while likewise a restraint in grandparental activities of one grandparent reduces the activities of the other. Therefore, grandparents living together will align their grandparental efforts.

Educational Status

Educational status is another relevant factor that was often controlled for. Pollet et al. (2007) showed that the more educated a grandparent was the more contact he had. Also Uhlenberg and Hammill (1998) found that grandparents with a higher educational attainment had less infrequent contact with their grandchildren. Likewise, Wood and Liossis (2007) reported that grandparents with an advanced educational status were emotionally closer to their grandchildren. On the other hand, data from (Fingerman, 2004; Kaptijn, Thomese, van Tilburg, & Liefbroer, 2010; Pollet et al., 2006) showed that grandparent's education was not a significant predictor for grandparental investment in their studies.

Uhlenberg and Kirby (1998) stated that it may not only depend on the educational status of grandparents alone, but that the difference of educational status to their grandchildren matters. The educational gap between grandparents and parents - educational status of grandchildren might not be fully attained yet - may indicate how good grandparents will come along with their grandchildren. The authors predicted that grandparents who had a more equal educational status with their grandchildren would have less difficulties to interact with their grandchildren then those who had significant less education than their grandchildren. They also noted that this influence might be smaller now than it was a couple of decades before.

Health Status

Another factor that influences grandparental investment is grandparental health status. Although grandmothers tend to be healthier than grandfathers at a given age (Kirchengast & Haslinger, 2008), health status did not predict investment differences in the study from Uhlenberg and Hammill (1998). But, it is assumed that grandparents with better health are more likely to frequently interact with grandchildren and therefore provide more grandparental investment as opposed to grandparents with a bad health status. However, there have been mixed findings. Chan and Elder (2000) and Wood and Liossis (2007) reported a positive connection, where grandparents with good health had a better relationship with their grandchildren. On the other hand, Silverstein and Long (1998) stated that grandparental health problems can increase contact with grandchildren, due to the need of support with bad health conditions. With decreasing health, grandparents will invest less in grandchildren, although frequency of contact may increase due to the need of support. It might therefore not be optimal to solely use frequency of contact as a measure of grandparental investment, as grandparent-grandchildren interactions work in both directions and their proportion varies with age.

Age

The factor of age influences grandparental investment through all three generations with age shifting in all three generations simultaneously. And, because age is also highly connected with other variables, like health status, available resources and family size, it is difficult to quantify age-effects on every level (Danielsbacka & Tanskanen, 2012). When considering implications from reproductive value and fertility, as pointed out before, the older grandparents become the more they should invest in their grandchildren. Results from Euler, Hoier, and Rohde (2009) and Smorti, Tschiesner, and Farneti (2012), however, revealed no influence of grandparents' age on grandparental solicitude. It must be noted that in the early work of Euler and Weitzel (1996) health status of grandparents was not controlled for. And due to the connection of age with health status which influences grandparental kin investment in the opposite direction, both effects might cancel out.

Again, with regard to reproductive value grandparents should invest more in grandchildren with a higher reproductive value which is related to the grandchildren's age. Till the adolescence of the grandchildren grandparental investment should be positively correlated with age, as the older the grandchildren become the more valuable they are in terms of fertility. This correlation should reverse after the peak of fertility. According to Euler and Michalski (Hrdy, 2007) the age of grandchildren correlated negatively with grandparental investment, but it must be noted that due to different survey design the true age effect may be undermined. Euler and Weitzel (1996), for example, asked grandchildren retrospectively with age ranging from 16 to 80. By not considering a possible non-linear relationship between age and grandparental investment (at least over the recorded age range) a false linear connection will be concluded.

Exposure

Also strongly related with age stands the combined demographic factor of exposure. A possible influence of such a factor was first mentioned by Uhlenberg and Hammill (1998). However, this idea was incorporated by Tran et al. (2009) for the first time. One of the two components of exposure is the demographic difference of age at first marriage. Mean age of first marriage and likewise the age of first children in Austria is about two years higher for men than for women[1]. This age difference accumulates over generations so that grandfathers are on average two years older

[1] Statistik Austria: `http://www.statistik.at/web_de/statistiken/bevoelkerung/eheschliessungen/index.html`

than grandmothers, while paternal grandparents are at the same time two years older than maternal grandparents, when they become grandparents. The second component is the difference in life expectancy. For example, in Austria mean life expectancy is around five years higher for women than for men[2]. In combination with the difference in age at marriage the mean overall possible exposure of grandparents for grandchildren differs depending on the type of grandparent and their life status. With the maternal grandmother as the base line the paternal grandmother has on average two years less, the paternal grandfather on average seven years less and the paternal grandfather on average nine years less exposure with their grandchildren in total. When considering this difference results from Tran et al. (2009) showed that sex-effects partly disappeared after implementing the exposure measure (along with distance). It is, therefore, crucial to control for exposure differences, for example, by only including participants with all four grandparents still living.

Socioeconomic Status

The socioeconomic status (SES) of grandparents might influence grandparental investment as well. According to Coall and Hertwig (2010) a higher SES resembles having more resources available that can be invested. Therefore, a general positive connection was assumed by the authors. Furthermore, under the Trivers-Willard hypothesis, parents with good conditions which can be equated with high SES, invest more in sons than parents with poor conditions, who, on the other side, preferably invest more in daughters (Trivers & Willard, 1973). Presumably, due to inter-sexual selection, women prefer men with more resources than competing men with less resources. Thus, men in poor conditions are less successful when it comes to mating, instead it would be fitness enhancing for low status parents to invest in daughters, as they have the possibility to mate men with higher status. The theoretical reason for high status parents to not invest in daughters but sons is that men can produce more offspring in total than women could and, therefore, investment in sons is more profitable. It is noteworthy that family conditions can change over generations and, therefore, investment strategies can do too. There is mixed support for the Trivers-Willard hypothesis in various societies (see Buss, 2005). This was reflected in the

[2]Statistik Austria: http://www.statistik.at/web_de/statistiken/bevoelkerung/demographische_masszahlen/demographische_indikatoren/index.html

findings from Euler and Weitzel (1996) who initially found a connection only for maternal grandparents.

Urban vs. Rural Background

A theory that builds upon the Trivers-Willard hypothesis is the matriliny-as-daughter-biased-investment hypothesis as it is lately called by Mattison (2011). It originally traces back to the theoretical considerations of Hartung (1985), according to whom daughter biased investment - a matrilineal inheritance - is more likely in societies with high paternity uncertainty, while in societies with low paternity uncertainty (e.g. societies where extra-pair copulation for women is highly restricted) patrilineal inheritance is more likely. Holden (2003) argued that besides paternity uncertainty the second factor of benefit from resources plays an important role. The key idea is that inherited resources may have a different impact on son's and daughter's reproductive success. For example, livestock in traditional postoral and agricultural societies may be more helpful for men than women descendant's reproductive success. These differences in benefit must be considered in combination with paternity uncertainty. The benefit for sons (BS) unlike the benefit for daughters (BD) are reduced by the degree of paternity uncertainty (P) of the belonging society. Mattison (2011) derived the equation

$$BS/BD = 1/P \tag{3.1}$$

for the equilibrium of inheritance into sons and daughters. It follows that if the benefit ratio is higher than the balanced $1/P$ ratio, it is more profitable to invest in sons (see Figure 4). The strategy to inherit resources into daughters would be adaptive if either, the costs due to paternity uncertainty would outweighs the benefits of inheritance into sons, or when sex-biased resources are less likely.

Holden (2003) presented data from a patrilineal and matrilineal society, that both supported this theory. Mattison (2011) also reported a matrilineal society that was mostly in accordance with the theory. Therefore, the size and the direction of the grandparental lineage-effect is associated with the degree of paternity uncertainty in a society and the ratio of benefits through inherited resources. This can explain why a reversed lineage-effect in the rural sample of Pashos (2000) indicated that paternal grandparents invested more in their grandchildren than maternal grandparents.

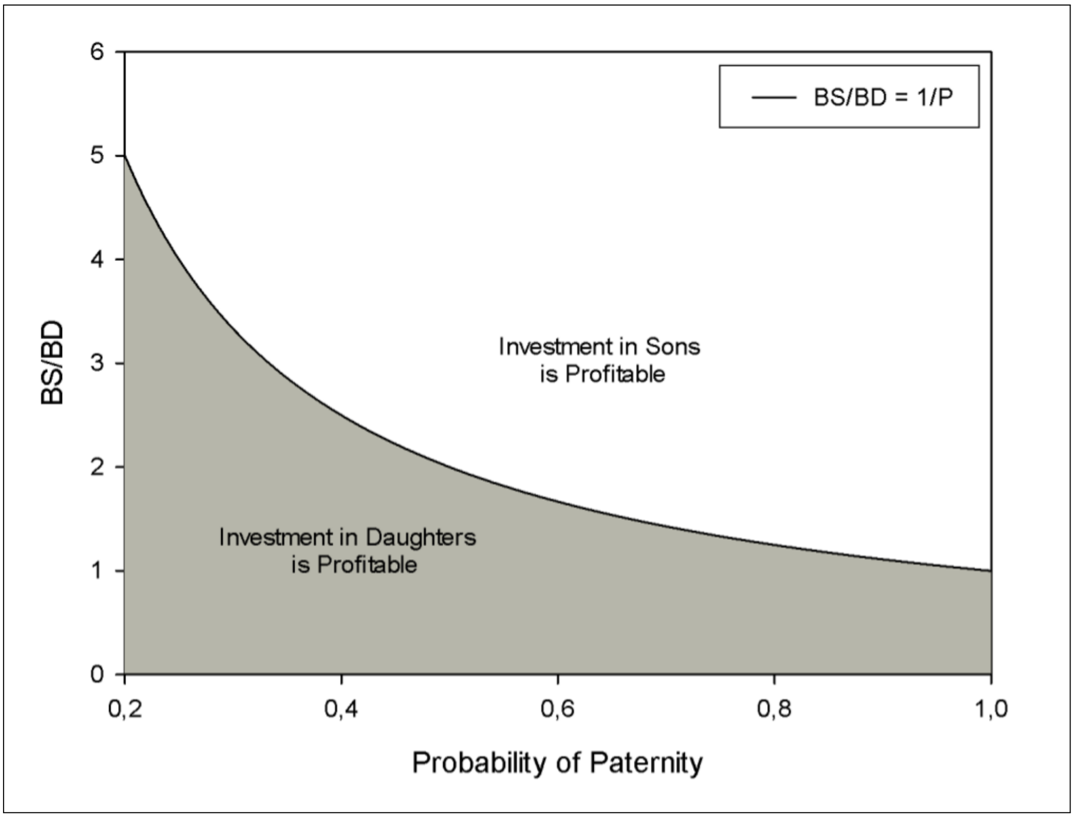


Figure 4: Equilibrium of inheritance of wealth in dependence on paternity uncertainty. Adapted from "Evolutionary contributions to solving the "matrilineal puzzle": A test of Holden, Sear, and Mace's model.", by S. M. Mattison, 2011, *Human Nature*, *22*, p. 71. Copyright 2011 by Springer Science+Business Media.

4. Methods of Previous Research

4.1. Survey Designs

Previous studies utilized different designs to obtain data on grandparental kin investment. In Table 1 all survey designs are listed and divided upon three main aspects which are discussed next.

The first major distinction can be made between surveys where data was obtained by either asking grandchildren or grandparents. Research started with the questioning of grandchildren as it was argued that grandparents might underlie pressure of social desirability (Euler & Weitzel, 1996; Laham et al., 2005). The argumentation continued

Table 1
Overview of different type of designs in grandparental kin investment research

	Asked grandchildren	Asked grandparents
Obtained data retrospectively	Euler and Weitzel (1996)[a] Pashos (2000)[a] Chrastil et al. (2006)[a] Pashos and McBurney (2008)[c] Tran et al. (2009)[a]	Pollet et al. (2006)[b,e] Pollet et al. (2007)[b,e] Danielsbacka et al. (2011)[b,e] Ghysels (2011)[b,e]
Obtained data presently	Salmon (1999)[d] Chan and Elder (2000)[e] Dubas (2001)[d] Laham et al. (2005)[d] Attar-Schwartz et al. (2009)[e] Bishop et al. (2009)[d] Coall et al. (2009)[e] Mann et al. (2009)[d] Pollet et al. (2009)[e] Tanskanen et al. (2011)[e] Danielsbacka and Tanskanen (2012)[e] Tanskanen and Danielsbacka (2012)[e]	Uhlenberg and Hammill (1998)[e] Fingerman (2004)[d] Michalski and Shackelford (2005)[d] Barnett et al. (2010)[e]

[a]Questions referred to the first seven years of life.
[b]Questions referred to the past 12 months.
[c]Questions referred to the childhood.
[d]Questions referred to the present.
[e]Analyzed data from other projects.

by stating that grandchildren's perception can be considered a proxy measure for grandparental kin investment because people tend to like others the same way others like them. Following this argumentation most researchers retrieved data by asking grandchildren. Still, it is not ruled out that grandchildren's perception might be biased as well.

However, difficulties arise when only asking one generation, as properties of the other two generations, who are involved, are largely ignored. Although, in some cases, the corresponding generation provides information about the other generations (e.g., Tran et al., 2009), these information will be incomplete and less accurate. Likewise, Hagestad pointed out that "taking only two generations into account may often create serious limitations" (2006, p. 329).

Another differentiation can be made upon the time of investment to which studies refer. Basically, there are two references; either surveys were asking retrospectively or they were asking about the current investment. For example Euler and Weitzel (1996) asked grandchildren retrospectively about their first seven years of life which was also done by Pashos (2000) and Tran et al. (2009). Unfortunately, researchers have not declared why in particular the period of the first seven years of life was chosen. Pashos and McBurney (2008) expanded this period to the period of childhood, but likewise did not state the reason for this particular period. A possible reason might be that grandchildren in question are not necessarily of young age. For example, in the sample of Euler and Weitzel (1996) the span of age ranged from 16 to 80 years. However, this bears a problem, as memories blur over time. By asking older people to remember more than 50, 60 or even 70 years back in time, to a point where people generally tend to not have many memories of, answers will be slightly distorted. Such a remembrance distortion might be influenced by more recent events which might be different from past memories overwriting the actual provided investment. It might be even confounded by the total exposure time with each grandparent which differs among type of grandparent as pointed out in Chapter 3.3.

A third difference between previous researches is that not all authors obtained and used their own data. A large quantity of papers used data from other projects, like

SHARE[1], NSFH2[2], IYFP[3], NKPS[4], MCS[5], FTP[6], sesam[7] and Involved Grandparenting and Child Well-Being Survey. On the one hand, using data from different resources allows for a more heterogeneous verification of possible grandparental differences which, however, makes it more difficult to compare findings, as every project uses a different operationalization of investment. Furthermore, some sources are used multiple times, hence, findings from different teams of scientists using the same data will most likely be similar if not identical resulting in some sort of reporting bias. For example, Pollet et al. (2006) and Pollet et al. (2007), Danielsbacka et al. (2011) and Ghysels (2011) as well as Tanskanen et al. (2011) and Danielsbacka and Tanskanen (2012) used the same data reporting similar results. Still, it is legitimate to use the same data to test new theories, like Chrastil et al. (2006) used data from Euler and Weitzel (1996) to test genetic relatedness hypothesis. However, because the initial survey was not directly designed for testing other hypothesis, results still might be biased, as important factors might not be considered, like the existence of opposite-sex siblings which according to SA-ZD are relevant for testing sex chromosomal relatedness. A general drawback of using data from other larger projects is that specific relevant moderators might not be measured; perceived resemblance, grandparent-parent relationship ties or birth order of grandchildren, for instance, are common missing variables among large cohort projects.

4.2. Operationalizations

Since no uniform definition of grandparental kin investment exists, the operationalization of grandparental kin investment differs from research to research. Authors used various items to depict investment or transformed items from other projects to fit their needs (see Table 4). Likewise, different predictors and moderators were used. The next paragraph gives a brief overview over the most common items used.

The most common measure for investment was frequency of contact between grandparents and grandchildren. Most of these authors were bounded to this measure

[1]Survey of Health, Ageing and Retirement in Europe
[2]National Survey of Families and Households
[3]Iowa Youth and Families Project
[4]Netherlands Kinship Panel Study
[5]Millennium Cohort Study
[6]Family Transitions Project
[7]Swiss Etiological Study of Adjustment and Mental Health

Table 2

Overview of different measurements in grandparental kin investment research

Measurement	Authors using the measurement
Frequency of contact	Uhlenberg and Hammill (1998), Silverstein and Long (1998), Salmon (1999), Dubas (2001), Mueller et al. (2002),Taylor et al. (2005), Pollet et al. (2006), Coall et al. (2009), Pollet et al. (2009), Mann et al. (2009), Barnett et al. (2010), Hurme et al. (2010), Segal and Marelich (2011)
Emotional closeness / Level of affection	Silverstein and Long (1998), Michalski and Shackelford (2005), Laham et al. (2005), Pashos and McBurney (2008), Attar-Schwartz et al. (2009), Bishop et al. (2009), Dubas et al. (2009), Monserud (2010), Mansson and Booth-Butterfield (2011), Michels et al. (2011), Mansson (2012)
Involvement	Dubas (2001), Mueller et al. (2002), Attar-Schwartz et al. (2009), Barnett et al. (2010), Mansson and Booth-Butterfield (2011), Danielsbacka and Tanskanen (2012), Tanskanen and Danielsbacka (2012)
Relationship quality	Chan and Elder (2000), Fingerman (2004), Kostelecky and Bass (2004), Taylor et al. (2005), Pollet and Nettle (2009), Michels et al. (2011)
Childcare	Meehan (2008), Kaptijn et al. (2010), Igel and Szydlik (2011), Aassve et al. (2012), Knudsen (2012)
Solicitude	Euler and Weitzel (1996), Pashos (2000), Tran et al. (2009)
Devoted time	Michalski and Shackelford (2005), Dubas et al. (2009), Ghysels (2011)
Level of concern	Gaulin et al. (1996), McBurney et al. (2002)
Authority, Punishment	Mueller et al. (2002), Dubas et al. (2009)
Money	Michalski and Shackelford (2005)
Willingness to help	Jeon et al. (2008)

as they used the data of other projects, where frequency of contact was the only investment related measure. In most cases, when authors obtained their own data, contact measures were not the only investment measure. If frequency of contact is used alone, it is problematic as it does not consider the reason for and the quality of the contact (Laham et al., 2005). Also, contact frequency is bidirectional, therefore, it is hard to distinguish between grandparental kin investment and the care-taking of grandparents by grandchildren.

Emotional closeness or the level of affection towards grandchildren or grandparents was the next most used item. This item does not directly measure investment and, hence, might be just a result or a cause for that. However, emotional closeness also may just represent a more feminine conception of investment. Spitze and Ward (1998) noted that some items might be gender-biased reflecting only one of many facets of investment which might be the case with affection.

Surveys using involvement as a measure generally tended to make a composite of questions concerning shared activities, care provision and interest. Using a composition of items seems more adequate with respect to the definition of grandparental kin investment which can be quite heterogenous (see Chapter 3.1). Because investment can be expressed and performed in a variety of ways, it is more adequate to include more than one item representing general grandparental kin investment.

The relationship quality between grandparents and grandchildren was also realized as a measure. This item, however, also depicts only one facet of many of investment. Also, grandchildren's cues used to derive relationship quality may stem from more recent events and responses to this question, likely, do not include actual investment provided during the childhood.

Provision of childcare as a different measurement was utilized some times. This item is directed retrospectively and because it concerns the early childhood of grandchildren answers from grandparents or parents might be more adequate than those of grandchildren. On the other hand, responses from grandparents might underly effects of social desirability as no one easily acknowledges to not have invested much or not at all in ones grandchildren. Parents, however, might tend to equalize the amount of investment from their own parents while investment from in-law parents might be degraded.

Solicitude, as a global measure for investment, seems to be a more adequate measure for investment, as the question refers to the total investment during a longer period of time. This question tends to induce cognitive processes in an individual so that the individual integrates different relevent aspects. Still, with only one question asked which refers to the sum of multiple changing factors, grandchildren in particular might tend to equalize answers for the different grandparents as he or she might not want to rate one higher than the other. Grandparents, again, might underly effects of social desirability. Additionally, because grandparents do not have a direct comparison for how much the other grandparents have invested, they use their own point of reference whereby answers from different grandparents might not be comparable.

A couple of other measures have been utilized occasionally. Generally, most researchers used only one measurement to depict investment while only a few used more composite measures. Furthermore, apriori differences due to the limitedness of measure specificity can arise with investment differences reflecting such bias. These limitations might also explain why some measures seem to support some differential hypothesis when other items do not.

Interestingly, paternity uncertainty which was used as the main explanation for differences between grandparents kin investment, was scarcely (directly nor indirectly) measured. Although, theoretically, men are to some degree uncertain about their paternity (implicitly) depending on the populations paternity uncertainty which can not easily be obtained, some men are more certain about their paternity (explicitly) than others, due to private concerns of possible infidelity. It is comprehensible that it is ethically questionable to ask men how certain they are to be someone's biological father as well as asking grandparents how certain they are someone's biological grandparent. However, it seems peculiar that unexplained differences between different types of grandparents are explained with paternity uncertainty which was not assessed directly nor with a substitute measure. It seems not correct that only because the incorporated predictors do not account for those differences paternity uncertainty predictions which seemingly follow the same orders, can be used as an explanation. Other unobserved variables might also follow the same order which would explain these differences. For example, exposure differences to grandparents (the afore mentioned accumulated demographic differences of grandparents; age differences between men and women at marriage and differences of life expectancy between men and women) which follows the same order, was not considered in previous research (Tran et al., 2009). Likewise, other explanatory variables might exist which contribute to the differences found between grandparents. However, as long as a supposedly explaining variable is not directly or indirectly measured it should be considered on how to assess this in further research.

4.3. Statistical Analysis

In previous research scientists used different statistical evaluation methods to analyze their data. Which method was used depended mostly on the type of design and the measurements used for obtaining investment data. Table 3 shows the different methods commonly used by different researchers.

Analysis of variance, *t*-tests, multiple regression and logistic regression were the most prevalent statistical methods in previous research. However, all of these

Table 3

Overview of different statistical evaluation methods

Methods	Authors using the method
AN(C)OVA / *t*-tests	Euler and Weitzel (1996), Gaulin et al. (1996), Salmon (1999),Pashos (2000), Hoier et al. (2001), Dubas (2001), McBurney et al. (2002), Laham et al. (2005), Michalski and Shackelford (2005), Chrastil et al. (2006), Jeon and Buss (2007), Jeon et al. (2008), Pollet et al. (2009), Smorti et al. (2012)
RP-AN(C)OVA	Salmon (1999), Bishop et al. (2009)
U-tests	Pashos (2000), Wood and Liossis (2007), Meehan (2008)
Correlation	Michalski and Shackelford (2005), Huber and Breedlove (2007)
Multivariate regression	King and Elder (1997), McBurney et al. (2002), Holden (2003), Apicella and Marlowe (2004), Kostelecky and Bass (2004), Taylor et al. (2005), Pashos and McBurney (2008), Coall et al. (2009), Tran et al. (2009), Hurme et al. (2010), Monserud (2010), Danielsbacka and Tanskanen (2012), Knudsen (2012), Tanskanen and Danielsbacka (2012)
Logistic regression	Uhlenberg and Hammill (1998), Mueller et al. (2002), Pollet et al. (2006), Pollet et al. (2007), Pollet and Nettle (2009), Kaptijn et al. (2010), Danielsbacka et al. (2011), Tanskanen et al. (2011), Aassve et al. (2012)
Fixed-effect model	Chan and Elder (2000)
Multilevel model	Silverstein and Long (1998), Fingerman (2004), Webster et al. (2008), Attar-Schwartz et al. (2009), Pollet et al. (2009), Tran et al. (2009), Ghysels (2011), Johow and Voland (2012)
Path model	Taylor et al. (2005), Barnett et al. (2010)

statistical methods underlies the assumption of independence of observations within and between groups. But, when grandchildren are used to rate all four *groups* of grandparents which was the case in most of the previous surveys, responses between groups will be highly dependent. Therefore, with the nature of intraclass correlation variances and standard errors of model parameters will be under- or overestimated (depending on the direction of intraclass correlation) resulting in in- or decreased true Type I error probabilities (Scariano & Davenport, 1987). Accompanied with in- or decreasing Type I error probabilities true Type II error probabilities, hence statistical power, de- or increases. The same problem resulting from violations of independence of observations applies to Mann-Whitney-*U* tests and correlations, as they underly the same assumption.

To overcome this problem, some researchers utilized a repeated-measures AN(C)OVA which, however, can cause a different problem for some statistical softwares as pointed out by Tran et al. (2009). In SPSS, for example, controlling for covariates within RP-AN(C)OVA will remove the influence of the covariates for every group. Therefore, covariates that differ between the specific groups, like residential proximity, age or marital status, cannot be matched with the group, so that it will be only removed for the specific groups, and will be erroneously implemented.

Multilevel models, as a good alternative, overcome problems due to the assumption of independence of observations and have additional advantages over general linear models; e.g. the possibility of incorporating cross-level interactions, the ability to model variability of covariates for each group and the flexibility to handle missing data (Field, Miles, & Field, 2012). This type of analysis, however, was less utilized in previous research, even though it is more suited for handling this kind of data.

Furthermore, most researchers have not pointed out the statistical prerequisites for their methods leaving it open if they have been checked for at all. For instance, normal distribution of the dependent variables have not been reported in most cases. Most papers also lack information regarding the statistical programs that were used for the calculations. It is also noteworthy that a few researchers only compare the most favored grandparent types. Due to this reduction information based on the first rank can not be generalized to other ranks, because grandparents who are never the favorite ones are not necessarily the least favored.

In most previous studies more women than men participated in the surveys which is a commonly known form of volunteer bias. However, this bias can be a problem for grandparental kin research, where the main effects of interest are the sex effects. It is possible that same-sex preferences due to non-balanced designs might superimpose actual sex-effect and it is, therefore, advised to balance participant upon their gender, in particular when grandchildren are asked.

Part II.

EMPIRICAL PART

The empirical part consists of five chapters. The first chapter points out the research objective of the present empirical survey including the formulation of specific research questions and hypotheses, which are derived from previous research. In the next chapter, the specific survey design is depicted and the assembly of the questionnaires is described. The third chapter contains the statistical analyses used and describes the acquired results. The results are then discussed in the penultimate chapter. In the last chapter conclusions with respect to the explanatory theories are drawn and limitations of the present survey as well as suggestions for further research are pointed out.

5. Research Objective of the Present Survey

As have been pointed out in the previous sections, different designs and statistical methods have been used in previous research to examine differential grandparental kin investment. Measurements of investment have been quite heterogenous, when a composite of measures is more appropriate with respect to the definition of grandparental kin investment. In most cases information on grandparental investment was obtained by asking grandchildren which led to highly dependent responses, additionally, leaving out relevant information from other generations. Also, some of the statistical methods that have been used are not suited for handling this kind of dependent data, which may have led to false conclusions.

An objective of the present empirical research of this thesis is the combination of different approaches that have been used so far. This includes the construction of an investment composition of different measures, which corresponds with the investment definition given in chapter 3.1. In addition, information on grandparental kin investment and their influential factors will be obtained by all three generations, namely, grandparents, grandchildren and the parental generation in between. The statistical analysis of the data will include a principal component analysis of the measurement items with the aim to construct a global investment measure. This measure will then be used as the dependent variable upon which a linear mixed model will be constructed, including moderators from all generations. With this approach the magnitude of the different moderators on grandparental kin investment can be determined, when the moderators can also be controlled for in order to test for differences between the four type of grandparents.

5.1. Research Questions

The main objective of the present research is to find out, whether and how grandparents systematically differ in the provision of investment for their grandchildren. Therefore, the main question of this research refers to the comparison of the four types of grandparents with respect to their gender, their lineage and the gender of grandchildren.

> **Research Question 1**
> Does grandparental investment differ between grandparents with respect to their sex, the sex of the parental generation (lineage) and the grandchildren's sex?

As there are many factors reported to have a possible influence on grandparental investment in a more general way, but also in a more discriminating way, another concern is to control for these moderators and analyze their influence.

> **Research Question 2**
> To what degree do moderators influence grandparental kin investment?

The next interest is, whether data obtained from either grandparents or grandchildren are comparable and yield similar results. Are information from parents also useful and comparable.

> **Research Question 3**
> Does reported grandparental kin investment from grandparents, grandchildren and parents yield similar results?

Because authors tend to use different measures for grandparental kin investment, it is also of interest whether different dependent variables yield different results concerning differential grandparental kin investment.

> **Research Question 4**
> Do different investment measures yield different results?

5.2. Hypotheses

The following hypotheses are derived from existing theories predicting differential grandparental investment or predicting an influence of moderators on grandparental investment. Hypotheses start on an aggregated level and are further relativized by differentiating between particular cases. Most hypotheses are formulated directionally (one-sided tests), as they are derived from theories, whereas other ones are undirected (two-sided tests).

> **Hypothesis 1.1**
> H_0 : Grandmothers and grandfathers invest equally in their grandchildren.
> H_1 : Grandmothers invest more in their grandchildren than grandfathers.

Grandchildren do not only have a single grandmother and grandfather but two of them each. The lineage of grandparents distinguishes same-sex grandparents from another.

> **Hypothesis 1.2**
> H_0 : Maternal and paternal grandparents invest equally in their grandchildren.
> H_1 : Maternal grandparents invest more in their grandchildren than paternal grandparents.

As the four sets of grandparents can be seen as a combination of their own sex and their lineage two sets of grandparents are indistinguishable in their investment, if the prior hypotheses are true. Their relation depends on the effect sizes of grandparent's sex and lineage.

> **Hypothesis 1.3**
> H_0 : Maternal grandfathers and paternal grandmothers invest equally in grandchildren.
> H_1 : Maternal grandfathers and paternal grandmothers invest differently in grandchildren.

According to the newer theory of sexually antagonistic zygotic drive, gender of grandchildren also play a role in grandparental kin investment; for some grandparents more than others.

> **Hypothesis 1.4**
> H_0 : Paternal grandmothers invest equally in their granddaughters and grandsons.
> H_1 : Paternal grandmothers invest more in their granddaughters than in their grandsons.

> **Hypothesis 1.5**
> H_0 : Paternal grandfathers invest equally in their granddaughters and grandsons.
> H_1 : Paternal grandfathers invest more in their grandsons than in their granddaughters.

Because perceived resemblance is supposed to be an indicator for paternity uncertainty it is likely that it can be used to predict differential grandparental kin investment.

Hypothesis 1.6

H_0 : Perceived similarity in resemblance does not have an influence on grandparental investment.

H_1 : The more similar grandchildren and grandparents are perceived, the more grandparental investment is provided.

The next couple of hypotheses concern all the moderators.

Hypothesis 2.1

H_0 : Grandchildren's birth order has no influence on grandparental investment.

H_1 : Middle-born grandchildren receive less investment from grandparents than first- or last-born grandchildren.

Hypothesis 2.2

H_0 : Relationship of the parental generation with the grandparental generation is not related with grandparental investment.

H_1 : The better the relationship of grandchildren's parents with grandparental generation, the more grandparental investment they receive.

Hypothesis 2.3

H_0 : Grandparents with urban and rural backgrounds invest equally in grandchildren.

H_1 : Paternal grandparents with a rural background invest more in grandchildren than maternal grandparents with a rural background, while maternal grandparents with an urban background invest more than paternal grandparents with an urban background.

Hypothesis 2.4

H_0 : Correspondence of educational status between grandparents and parents is not related with grandparental investment.

H_1 : The larger the educational difference between grandparents and the parental generation, the less grandparental investment is provided.

Hypothesis 2.5

H_0 : Health status of grandparents is not related with grandparental kin investment.

H_1 : The healthier grandparents are, the more grandparental kin investment they provide.

Hypothesis 2.6

H_0 : Age of grandparents is not related with grandparental investment.

H_1 : The older grandparents are, the more grandparental investment they provide.

Hypothesis 2.7

H_0 : Grandparental co-residence is not related with grandparental investment.

H_1 : Grandparents living separated invest less than grandparents living together, especially grandfathers.

Hypothesis 2.8

H_0 : Grandparents with high and low SES invest equally in grandsons and granddaughters.

H_1 : Grandparents with high SES invest more in grandsons than granddaughters, while grandparents with low SES invest more in granddaughters than grandsons.

Hypothesis 2.9

H_0 : Residential proximity does not influence grandparental investment.

H_1 : Closer living grandparents provide more grandparental investment.

Hypothesis 2.10

H_0 : Family size is not related with the amount of grandparental investment.

H_1 : The larger the family size of grandparents the less they invest in their grandchildren.

Hypothesis 2.11

H_0 : The order of grandchildren provision is not relevant for grandparental investment.

H_1 : Grandchildren of families who provided grandchildren first receive more grandparental investment than grandchildren of families who provided grandchildren later.

The last three hypothesis concern the comparability of information.

Hypothesis 3.1

H_0 : Grandparents and grandchildren provide equivalent information regarding grandparental investment.

H_1 : Grandparents' information regarding grandparental investment differs from grandchildren's information.

Hypothesis 3.2

H_0 : Parents provide equivalent information regarding grandparental investment as grandchildren and/or grandparents.

H_1 : Parents' information regarding grandparental investment differs from grandchildren's and grandparents' information.

Hypothesis 4

H_0 : Different investment measures provide the same results with regard to sex- and lineage effects of grandparents.

H_1 : Different investment measures provide different results with regard to sex- and lineage effects of grandparents.

6. Survey Design

The present survey was constructed to obtain data from all three generations of the participating families. Grandchildren as well as grandparents primarily provided data on grandparental investment, while information from parents were mainly used to construe family constellations, gain information on influential factors and partly examine comparability of grandparental investment. A couple of conditions were set in advance for the selection of families.

First, it was considered as necessary that only families were recruited, where all four biological grandparents were still alive and willing to participate. This way it was assured that exposure differences yielding from early death, which result mainly due to sex-specific demographic differences, were held constant. Results of Tran et al. (2009) suggested that such differences exert a considerable influence on measures of investment. The effect of exposure was, therefore, controlled for.

Another precondition was that families should contain siblings of at least one grandson and one granddaughter, in order to test specific hypotheses regarding selective grandparental investment. Including families with grandchildren of both gender made it more difficult to find corresponding families, however, tests on sex specific interaction terms between grandchildren and grandparents were more powerful. Another important advantage of this precondition was that the gender of participants was quite balanced this way.

A third minor condition was that grandchildren had to be at least twelve years old. This served the purpose to ensure that grandchildren understood the whole questionnaire. Due to this condition the questionnaires could refer to the first 12 years of the childhood. This period was chosen, because the reproductive value of individuals in this period is almost equal and constant.

If all three conditions were met, contact with a family member was initiated. Specific questionnaires for all relevant members were prepared. The contacts person was then instructed and asked to distribute and recollect all questionnaires.

6.1. Operationalization of Investment

The definition of grandparental kin investment provided in chapter 3.1 claims that there are different options one can choose to provide investment. Altogether, previous researchers have used different items to gauge investment, as is layed out in chapter 4.2. However, most authors have used only a single item to depict investment, with a few exceptions. As this empirical work aims to cover most of the different aspects of grandparental kin investment, the most common items used in previous surveys were collected and integrated. The selection of proper items was oriented at the existing collection of items from the work of Tanskanen et al. (2011). Additional items were generated to fill in gaps of other investment options following the qualitative work of Mansson (2012). Different themes of grandparental behavior patterns towards grandchildren were categorized by Mannsson and it was, therefore, intentioned to include items from all of these different categories. Table 4 shows the set of 26 items that have been selected for this survey. To ensure uniformity, all items were transformed into a "How often ..." phrase and were provided with the exact same 7-point likert scale ranging from "never" to "always".

Additionally, two items, solicitude and emotional closeness which were used by Euler and Weitzel (1996); Pashos (2000); Tran et al. (2009) to depict overall investment in Germany, were included in the questionnaire as well, in order directly compare findings with the three previous works and to analyze their adequacy in depicting grandparental kin investment. Solicitude refers to the general investment of grandparents ("Wie sehr hat er/sie sich generell um mich gekümmert?"). Emotional closeness refers to the emotional affection towards someone ("Wie emotional verbunden habe ich mich mit ihm/ihr gefühlt?") and is just a result, by-product or cause for investment. Both items were provided with a 7-point likert scale ranging from "not at all" to "very much".

6.2. Instrumentation

Since three generations ought to be participating in this survey a questionnaire for each generation was assembled simultaneously. All three questionnaires started out with information on the procedure, anonymity, data protection and participants

Table 4

Overview of the 26 questions on grandparental kin investment

Item	Question
Item 1	Wie oft umarmte/küsste er/sie mich beim Begrüßen/Verabschieden?
Item 2	Wie oft umsorgte er/sie mich? (z.B. Bekochen, Jause herrichten)?
Item 3	Wie oft ging er/sie mit mir Hand in Hand? (z.B. bei Ausflügen)
Item 4	Wie oft verreiste er/sie mit Ihnen?
Item 5	Wie oft hatte er/sie mit mir per Telefon, Brief oder Email Kontakt?
Item 6	Wie oft hatte ich die Möglichkeit Fähigkeiten von ihm/ihr zu erlernen? (z.B. Kochen, Stricken, Dinge Reparieren, Schwimmen, etc.)
Item 7	Wie oft hat er/sie mich persönlich getroffen?
Item 8	Wie oft passte er/sie auf mich auf, wenn dies notwendig war?
Item 9	Wie oft ging er mit mir gemeinsam Freizeitaktivitäten nach? (z.B. Ausflüge, Spielen, Malen, Kochen, Lesen, etc.)
Item 10	Wie oft war er/sie bei meinen Geburtstagen anwesend?
Item 11	Wie oft machte er/sie mir Komplimente?
Item 12	Wie oft ließ er/sie mich wissen, dass er/sie mich lieb hat?
Item 13	Wie oft sagte er/sie mir, dass er/sie gerne mit mir Zeit verbringt?
Item 14	Wie oft machte er/sie mir Geschenke, auch wenn kein besonderer Anlass dafür bestand?
Item 15	Wie oft machte er/sie mir Geschenke zu Weihnachten, zum Geburtstag oder zum Namenstag?
Item 16	Wie oft schenkte er/sie mir Geld zu Weihnachten, zum Geburtstag oder zum Namenstag?
Item 17	Wie oft gab er/sie mir Geld auch wenn kein besonderer Anlass dafür bestand?
Item 18	Wie oft besprach er/sie mit mir meine Probleme?
Item 19	Wie oft besprach er/sie mit mir meine Zukunftspläne?
Item 20	Wie oft erzählte er/sie mir von seinen/ihren persönlichen Erfahrungen?
Item 21	Wie oft fragte er/sie mich nach meiner Verfassung?
Item 22	Wie oft fragte er/sie mich nach meinen Erlebnissen in der Schule oder im Freundeskreis?
Item 23	Wie oft gab er/sie mir Ratschläge?
Item 24	Wie oft bestärkte er/sie mich in meinen Interessen/Hobbies?
Item 25	Wie oft besuchte er/sie eine Veranstaltung, an der ich teilgenommen habe? (z.B. Sport-,Theater- oder Musikveranstaltungen)
Item 26	Wie oft war er/sie für mich eine Vertrauensperson, ein Berater oder ein Freund?

Note. Items stem from grandchildren's questionnaire and are adapted in the grandparents' questionnaire.

rights, followed by a section asking for sociodemographic background information. The next section of the questionnaire was similar for grandchildren and grandparents, whereas it was different for the parental generation. Grandchildren and grandparents were presented with a number of sets of the 26 investment questions, where the number of sets was the number of persons who were referred to; grandchildren got four sets concerning each of the four grandparents, while grandparents got a set for each participating grandchild. The 26 items were randomized within such a set and the sets themselves were randomized as well. Additionally, after each set of questions grandparents were asked a series of questions referring to the time of the specific grandchildren's childhood; a question on their well being on a 5-point likert scale ranging from "very bad" to "very good", a question on their residential situation with the option to choose between "living together" or "living separated", a question concerning the travel-time to the specific grandchildren with preferred means of transportation to be answered in minutes, two questions concerning the perceived physical resemblance and the perceived similarity in personality to be answered on a 7-point likert scale ranging from "not at all" to "very much".

Parents, on the other hand, were asked to provide information regarding the family structure - number and age of children, siblings and siblings' children - and the relationship quality with their parents and parents in-law (respectively the grandparental generation) on a 7-point likert scale ranging from "poor" to "outstanding". All three generations were then asked the additional solicitude question for each relevant grandchildren-grandparent combination. Additionally, grandchildren and grandparents were asked about their emotional closeness regarding the referred person in questions. In addition, grandparents were asked to estimate the number of cuckoo children in the urban or rural region where they grew up. The instruction for this item was similar to that given by Voracek et al. (2009). At the end, all participants were thanked for their participation and asked to put the questionnaire back in the envelope and properly seal it.

7. Implementation and Procedure

7.1. Sample Statistics

Due to the specific preconditions set, it was expected that relevant families were hard to reach. Therefore, in order to reach as many relevant families as possible, invitations in more than 200 facebook groups, all related with one of the keywords *Österreich*, *Wien*, *Linz*, *Graz*, *Salzburg*, *Share and Care*, *Eltern* and *Familien*, were spread. Beside additional word-of-mouth advertising, multiple recruitment posters were hung in the *Main Building*, the *New Department Building* and the *Campus* of the *University of Vienna* as well as in the *Faculty of Psychology*, in the *Institute of Medical Physics*, in the *Afro-Asian Institute*, in the *Faculty of Law*, in the *Institute for Organic Chemistry*, in the *Faculty of Computer Science*, in the *University of Natural Resources and Life Sciences*, in the *Education, Linguistics and Comparative Literature Library* and in the *Public Library Vienna*. The active recruitment phase took place in April and Mai 2013 with the extension to return questionnaires till the end of June.

The actual process of recruitment was similar for all families. One member of a relevant family, who became aware of the survey, wrote me an email or a message via facebook announcing their interest; in some cases contact via phone was established. It was then made sure that all preconditions were really fulfilled and that all relevant family members of this person were likely to participate. The contact participant was then asked to give the first names of the relevant grandchildren so that the questionnaires could be prepared accordingly. The first names of the grandchildren were relevant because the parent's and the grandparent's questionnaires were referring to those specific grandchildren and when more than one grandson or granddaughter were present the reference would be unclear. Each of the questionnaires (a questionnaire for each of the four grandparents plus a questionnaire for each of the two parents plus a questionnaire for each of the relevant grandchildren) were put in an unsealed envelope and all of them were put in a larger envelope which was then either mailed to the contacts person or handed over personally, depending on the place of residence. The contact member was then instructed to forward the envelopes with questionnaires to all of the relevant family members, recollect the sealed envelopes afterwards and send or hand them back over to me, jointly.

Initially, 52 suited families were recruited to which questionnaires have been distributed. However, only 46 out of these 52 families (88.5%) returned the questionnaires in the end. Of the returned questionnaires only those of 40 families were eventually included in the final dataset. One family was excluded due to non-native speaking grandparents, who had problems with the questionnaire. Two families were excluded because the grandsons refused to participate. Likewise two other families were excluded as at least two grandparents refused to participate. An additional family was excluded as both parents refused to give information, which led to the lack of relevant information for some of the crucial predictors. In the 40 remaining families both parents, all four grandparents and at least one granddaughter as well as one grandson answered at least 98% of the provided questionnaire.

The final dataset included 337 participants of which 160 were grandparents, 80 parents and 97 grandchildren (49 granddaughters and 48 grandsons). The overall grandchildren's age ranged from 12 to 31 (M = 20.61, SD = 4.29), when the granddaughters' age ranged from 12 to 29 (M = 21.08, SD = 3.73) and the grandsons' age ranged from 13 to 31 (M = 20.13, SD = 4.80). The overall grandparents' age ranged from 60 to 91 (M = 73.99, SD = 5.70); maternal grandmothers' age ranged from 60 to 82 (M = 72.34, SD = 5.56), the maternal grandfathers' age ranged from 65 to 91 (M = 74.64, SD = 5.36), the paternal grandmothers' age ranged from 65 to 85 (M = 72.96, SD = 5.12) and the paternal grandfathers' age ranged from 66 to 87 (M = 76.06, SD = 5.51). Further statistics of the sample are presented in Table 5 and 6.

7.2. Data Handling and Processing

As the 26 items were supposed to measure parts of grandparental investment, it was of interest to find the underlying structure of those items. It was then intentioned to conduct a global investment measure upon which further analysis regarding differential grandparental kin investment was carried out. The graphical interface of SPSS (Version 21) was used for the data entry. The final dataset was then imported in R (Version

Table 5
Statistics of metric variables of the sample

	Mean	Median	SD	Skewness	Minimum	Maximum
Overall						
Resemblance	3.02	3	1.35	0.34	1	7
Age difference	53.39	53	6.36	−0.04	37	71
Health of grandparent	4.14	4	0.76	−0.92	1	5
Maternal relationship quality	3.89	4	1.37	0.18	1	7
Paternal relationship quality	3.74	4	1.29	0.46	1	7
Education difference	1.41	1	1.03	0.24	0	4
Distance	41.23	30	63.82	3.52	2	390
Family size	9.01	7	6.30	2.21	2	31
Maternal grandmother						
Resemblance	2.82	3	1.26	0.28	1	6
Age difference (GP - GC)	51.73	52	6.36	−0.07	38	66
Health of grandparent	4.09	4	0.77	−0.45	2	5
Maternal relationship quality	4.38	5	1.50	−0.30	1	7
Paternal relationship quality	3.48	3	1.17	0.66	1	6
Education difference	1.79	2	1.07	0.11	0	4
Distance	40.87	30	50.91	3.39	1	300
Family size	9.11	7	6.35	2.16	2	31
Maternal grandfather						
Resemblance	2.87	3	1.26	0.56	1	7
Age difference	54.03	54	6.22	0.20	40	71
Health of grandparent	4.30	4	0.63	−0.34	3	5
Maternal relationship quality	3.99	4	1.20	−0.06	1	6
Paternal relationship quality	3.44	3	1.17	0.61	1	6
Education difference	1.21	1	1.14	0.41	0	3
Distance	41.19	30	46.83	3.39	1	300
Family size	9.11	7	6.35	2.28	2	31
Paternal grandmother						
Resemblance	3.08	3	1.46	0.08	1	6
Age difference	52.35	52	5.98	−0.13	37	65
Health of grandparent	4.07	4	0.70	−0.48	2	5
Maternal relationship quality	3.64	4	1.38	0.53	1	7
Paternal relationship quality	4.13	4	1.47	0.03	1	7
Education difference	1.60	2	0.91	0.21	0	4
Distance	40.73	20	74.84	3.53	1	390
Family size	8.93	7	6.32	2.27	2	31
Paternal grandfather						
Resemblance	3.33	3	1.37	0.46	1	7
Age difference	55.45	55	6.31	−0.22	39	70
Health of grandparent	4.10	4	0.91	−1.49	1	5
Maternal relationship quality	3.54	3	1.27	0.40	1	7
Paternal relationship quality	3.91	4	1.23	0.49	2	7
Education difference	1.06	1	0.83	−0.12	0	2
Distance	42.13	20	77.67	3.34	1	390
Family size	9.01	7	6.32	2.24	2	31

3.0.1) and used for all further analyses.

After all questionnaires were entered in the dataset, the next step was the imputation of missing responses on the 26 investment items. An imputation was necessary, because principal component analysis does handle missing data by listwise deletion which does not only reduce the sample size and thus statistical power, but also due to the drop of a a complete sequences of responses of one participant would have made the other response sequences of the same person less informative. For example, if a particular grandchildren had a missing for an item concerning the maternal grandfather, this would have led to the deletion of the whole series of responses regarding the maternal grandfather in the principal component analysis. For the calculation of the principal components this would have not been a problem, besides the reduced statistical power due to the sample reduction. However, because the subsequent calculation of factor scores can only be made for complete sequences the factor score for the maternal grandfather would have been missing which would make the factor scores for the other three grandparents less informative. Therefore, all 79 missing responses (one missing for item 24; two missings for item 1, 3, 8, 9, 14, 15, 16, 25 and 26; three missings for item 4, 7 and 20; four missings for item 11; five missings for item 5, 19 and 21; six missings for item 10; seven missings for item 18; eight missings for item 23; eleven missings for item 13) of a total of 20280 responses ($= 0.39\%$) were sequentially imputed using the hotdeck algorithm of the VIM package (Version 3.0.3.1).

In the next step looking at the items themselves revealed three problematic items. Item 10 with a median of 7 on the 7-point likert scale and skewness of -1.54, item 15 with a median of 7 and skewness of -2.41 as well as item 16 with a median of 6, skewness of -0.80 and a mean intercorrelation of .10 with all other items were considered inappropriate. Looking at the item content of the three items which concern the amount of birthday-visits, the number of times money or presents were given on birthday, Christmas or names-day event, explained their characteristics, as those actions are commonly performed by nearly any grandparent. It was, therefore, reasonable to exclude those items for further analysis as they did not reflect a discriminating factor of grandparental kin investment.

In addition, a couple of demographic variables, that were later used as predictor variables, had to be calculated and combined first. The information given by both parents were used to calculate the family size for each grandparent during the childhood of each grandchild in question. This was calculated as the sum of grandchildren each grandparent had during the childhood of the grandchildren in question. For further use, this variable was transformed with the natural logarithm as it was positively skewed by 2.21. Likewise, the distance between grandparents and grandchildren given in minutes was transformed with the natural logarithm as it was positively skewed by 3.49. Age difference between grandchild and grandparent was calculated since the age of grandchild could be ignored with the reason that questions referred to their childhood and the age of a specific grandparent was different for each grandchild's sibling during that time. Thus, calculating age difference as an indicator for the influence of grandparents' age seemed appropriate. In addition, information of both parents and grandparents concerning their background - rural versus urban - were combined into a single factor, to reduce multicollinearity as the background information of both parents and grandparents correlated significantly; between mothers and fathers r_{pb} = .507 (p < .001), between mothers and maternal grandparents r_{pb} = .44, (p < .001) and between fathers and paternal grandparents r_{pb} = .44 (p < .001). The newly combined factor had three levels with the information of whether the specific grandparent shared an urban or rural background with the parental generation or whether parents had an urban background when grandparents had a rural background. The situation of a parent with a rural background when grandparents had an urban background did not exist though. Two questions regarding the perceived resemblance of physical and personality were simply combined as a mean measure of both, as both correlated highly (r_{pb} = .558, p < .001). Socioeconomic status was recoded into a three level factor with low, medium and high as testing for specific interaction terms of interest with sex of grandchildren made this necessary. An additional variable *provision* was coded indicating whether the parental generation was giving the first, middle or last born grandchildren to the maternal and paternal side of grandparents. Table 6 shows the distribution of frequency for each category of the categorical variables used.

7.3. Global Investment Measure

The overall Kaiser-Meyer-Olkin factor (KMO) of 0.94 on the 23 remaining items verified the sampling adequacy for the use of principal component analysis which is considered 'superb' (Field et al., 2012). Except for item 3 and 20 whose KMO were

Table 6
Statistics of categorical variables of the sample given in percent per category

	Category 1	Category 2	Category 3
Overall			
Birth order of grandchildren	39.2	24.2	36.6
Socioeconomic status of grandparents	5.9	61.1	33.0
Co-residence of grandparents	48.5	51.5	
Parent-grandparent background	46.9	22.4	30.7
Provision of grandchildren	61.9	14.9	23.2
Maternal grandmother			
Birth order of grandchildren	39.2	23.7	37.1
Socioeconomic status of grandparents	10.3	68.0	21.6
Co-residence of grandparents	45.4	54.6	
Parent-grandparent background	47.4	23.7	28.9
Provision of grandchildren	64.9	14.4	20.6
Maternal grandfather			
Birth order of grandchildren	39.2	23.7	37.1
Socioeconomic status of grandparents	6.2	70.1	23.7
Co-residence of grandparents	45.4	54.6	
Parent-grandparent background	47.4	22.7	29.9
Provision of grandchildren	63.9	14.4	21.6
Paternal grandmother			
Birth order of grandchildren	39.2	24.7	36.1
Socioeconomic status of grandparents	7.2	48.5	44.3
Co-residence of grandparents	51.5	48.5	
Parent-grandparent background	47.4	17.5	35.1
Provision of grandchildren	58.8	15.5	25.8
Paternal grandfather			
Birth order of grandchildren	39.2	24.7	36.1
Socioeconomic status of grandparents	57.7	0.0	42.3
Co-residence of grandparents	51.5	48.5	
Parent-grandparent background	45.4	25.8	28.9
Provision of grandchildren	59.8	15.5	24.7

Note. Birth order of grandchildren (Category 1 = first, Category 2 = middle, Category 3 = last), Socioeconomic status of grandparents (Category 1 = low, Category 2 = medium, Category 3 = high), Co-residence of grandparents (Category 1 = living together, Category 2 = living separated), Parent-grandparent background (Category 1 = both rural, Category 2 = parent urban and grandparent rural, Category 3 = both urban), Provision of grandchildren (Category 1 = first, Category 2 = middle, Category 3 = last)

0.76 and 0.82, which is still 'good', items generally had a KMO above 0.90. Bartlett's test of sphericity (χ^2 = 10229.9, df = 253, p < 0.001) indicated sufficient correlations among the items in order to utilize a principal component analysis. Additionally, a parallel analysis with all 23 remaining items including responses from grandchildren and grandparents was carried out using the psych package (Version 1.3.2) in order to find the number of underlying components. Parallel analysis was repeatedly suggested to be more accurate in find the actual number of components (e.g., Lance, Butts, & Michels, 2006) as compared to the simple K1 rule, where the number of components chosen equals the number of components with eigenvalue larger than 1; this simplification tends to overextract the actual number of components. Therefore, a parallel analysis was carried out which suggested three components with eigenvalue larger than the 95 percentile of eigenvalues obtained from simulated random numbers over 1000 datasets. This number of components was visually supported by the elbow criteria of the scree-plot.

Consequently, a principal component analysis with oblique rotation on three factors was carried out to identify the corresponding items and their factor loadings. Oblique rotation was chosen because the underlying structure was not considered independent as all items somehow belong to the concept of investment. Table 7 shows the pattern and structure matrix with ordered factor loadings after the oblique rotation. The pattern matrix depicts the unique standardized distribution of each item to the respective factors with the influence of all other items been canceled out. The structure matrix, on the other hand, represents the correlations between the items and the respective factors. When for an orthogonal rotation both matrices are the same they are not for the oblique rotation and, therefore, should both be considered for the interpretation of factors. Thus, the examination of item contents clustered on each factor led to the following labeling of the three factors: Factor 1 = verbal interest and support; Factor 2 = nonverbal interaction; Factor 3 = unexpected presents.

Upon the pattern matrix, which respresent the item loadings on each factor, all compositions except for item 1 and item 5 were converted into the equivalent structural equation model using the lavaan package (Version 0.5-14). Item 1 and item 5 were not included due to small loadings and considerable cross-loadings on all three factors. Additionally, a hierarchical general factor was modeled on top of the three facets as all items belong to the theoretical construct of investment.

Table 7
Obliquely rotated factor loadings

Item	Pattern matrix Factor 1	Pattern matrix Factor 2	Pattern matrix Factor 3	Structure matrix Factor 1	Structure matrix Factor 2	Structure matrix Factor 3
Item 19	**0.86**	−0.18	−0.03	**0.74**	0.30	0.21
Item 22	**0.81**	0.01	−0.07	**0.79**	0.45	0.20
Item 21	**0.78**	−0.05	0.05	**0.76**	0.40	0.29
Item 24	**0.75**	0.06	−0.01	**0.78**	0.49	0.26
Item 11	**0.69**	−0.05	0.24	**0.74**	0.41	0.46
Item 18	**0.66**	0.08	0.04	**0.72**	0.47	0.27
Item 12	**0.63**	0.07	0.22	**0.74**	0.48	0.44
Item 13	**0.62**	0.15	0.14	**0.75**	**0.54**	0.38
Item 26	**0.61**	0.31	−0.05	**0.77**	**0.65**	0.23
Item 23	**0.53**	0.31	−0.08	**0.68**	**0.59**	0.17
Item 20	**0.53**	0.27	−0.25	**0.60**	**0.51**	−0.01
Item 8	0.01	**0.78**	0.09	0.49	**0.81**	0.29
Item 7	−0.14	**0.76**	−0.12	0.25	**0.65**	0.02
Item 9	0.13	**0.69**	0.05	**0.54**	**0.78**	0.26
Item 4	−0.07	**0.67**	0.07	0.33	**0.64**	0.21
Item 2	0.04	**0.63**	0.24	0.48	**0.72**	0.41
Item 6	0.21	**0.62**	−0.14	**0.51**	**0.70**	0.08
Item 3	0.08	**0.58**	0.20	0.48	**0.68**	0.37
Item 25	0.17	**0.56**	−0.07	0.46	**0.63**	0.13
Item 17	0.02	−0.03	**0.83**	0.28	0.19	**0.83**
Item 14	0.05	0.11	**0.80**	0.38	0.34	**0.85**
Item 5	0.27	0.20	0.34	**0.50**	0.44	0.48
Item 1	0.23	0.28	0.30	0.49	0.49	0.45
Eigenvalues	6.07	4.60	2.11			
Proportion of variance	0.26	0.20	0.09			
Cronbach α	0.92	0.86	0.81			

Note. Factor loadings over 0.50 appear in bold.

In the next step, all items that were suggested by modification indices to have serious cross-loadings to other factors or residual connections to other items were iteratively eliminated, starting with the largest one. It was intentioned to simplify the model by removing improper items instead of adding constraints, with the overall aim of improving the model-fit. This elimination process was repeated until a set cut-off of 0.05 of the Root Mean Square Error of Approximation (RMSEA) was reached, which is assumed to indicate a good model-fit. This way another 9 items were removed from the model leaving the final model with 12 items, of which five items loaded on the first factor, five items on the second factor and two items on the last factor. The standardized factor loadings are presented in Table 8 and the model-fit indices are presented in Table 9. All model fit indices were very good except for the Chi-square test which, however, is vulnerable to sample sizes larger than 400 becoming rather quick significant, which, presumably, was the case due to multiple responses of the participants.

Table 8
Standardized factor loadings

Item	Factor 1	Factor 2	Factor 3	G Factor
Item 26	.83			
Item 13	.72			
Item 24	.74			
Item 22	.71			
Item 18	.66			
Item 9		.81		
Item 6		.69		
Item 3		.66		
Item 25		.59		
Item 4		.58		
Item 14			.99	
Item 17			.69	
Factor 2				.92
Factor 1				.90
Factor 3				.43

Table 9
Model-fit indices

Index	
χ^2	130.851
df	51
p of χ^2 test	< .001
χ^2/df	2.566
RMSEA	0.045
RMSEA lower CI	0.035
RMSEA upper CI	0.054
SRMR	0.025
CFI	0.979
NNFI	0.973

Factor scores for all three factors and the general investment factor were calculated using the *predict()* function of the lavaan package, which uses the regression method to compute the factor scores. Mean scores for each type of grandparent of the calculated investment measure are presented in Table 10 next to emotional closeness and solicitude, which were obtained separately. Figure 5, 6, 7, 8 and 9 shows the general distribution of those additionally obtained items, whereas the distribution of the global investment scores followed a normal distribution with mean 0 and standard deviation of 1 as provided by the function.

7.4. Implementation of a Linear Mixed Model

In the next step the influence of multiple covariates on grandparental investment as well as fixed- and random-effects were modeled. The nature of data, namely the dependency of responses and cross-level interactions, made it necessary to expand a GLM approach, as already pointed out in Chapter 4.3. In order to adequately model

Table 10

Mean scores of measurements for type of grandparent before the implementation

	Calculated investment		Emotional closeness		Solicitude		
	GC	GP	GC	GP	GC	P	GP
Maternal grandmother							
Mean	0.23	0.10	5.33	6.10	5.82	5.39	5.45
SD	1.06	0.85	1.41	1.22	1.46	1.40	1.31
Maternal grandfather							
Mean	−0.14	−0.30	4.87	5.88	5.10	4.63	4.23
SD	0.94	0.86	1.63	1.13	1.62	1.57	1.57
Paternal grandmother							
Mean	0.29	0.10	5.24	6.22	5.55	5.14	4.93
SD	0.94	0.74	1.54	0.97	1.44	1.34	1.64
Paternal grandfather							
Mean	−0.13	−0.17	4.50	5.87	4.73	4.48	4.67
SD	0.85	0.87	1.54	1.24	1.58	1.56	1.53

the data, a Linear Mixed Model (LMM) was designed using the lme4 package (Version 0.999999-2).

The design of the LMM was done stepwise oriented at the five steps proposed by Hox (2010). The calculated general investment scores for grandchildren from the prior step were used as the dependent variable in the main model. All models except for the intercept-only and random-intercept model, which are left out for brevity, are presented in Table 11. Starting with the second model all models include random intercepts for every grandchild asked and family he or she belonged to. In addition, the third model incorporated the two main variables of interest, the person of interest, respectively, the type of grandparent and the perceived resemblance. In the fourth model fixed-effects of grandchildren and grandparents were added simultaneously as including them stepwise has not decisively changed the estimates. The fifth model included parent-grandparent factors which affected the effect of co-residence of grandparents to become insignificant. In the sixth model additional family factors were included which, likewise, made the effect of age difference and health status insignificant. The seventh model incorporated random slopes allowing the effect of the person of reference respectively type of grandparent to vary for the grandchildren questioned, which did not affect the estimates and their significance, when it raised R^2 by .34. In the last and final model cross-level, interactions were added but special attention had to be payed on the interpretation of main effects of the included variables. Figure 10 shows the distribution of residuals indicating a normal distribution of error terms and Figure 11

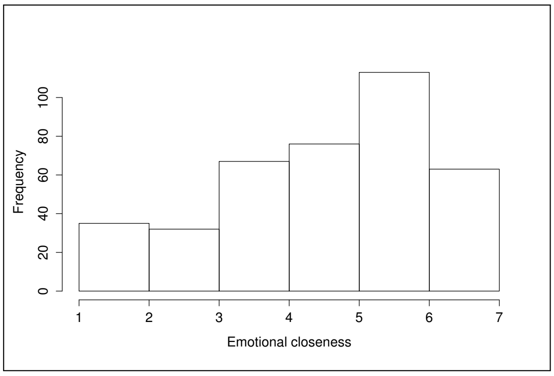


Figure 5: Overall distribution for grandchildren's emotional closeness

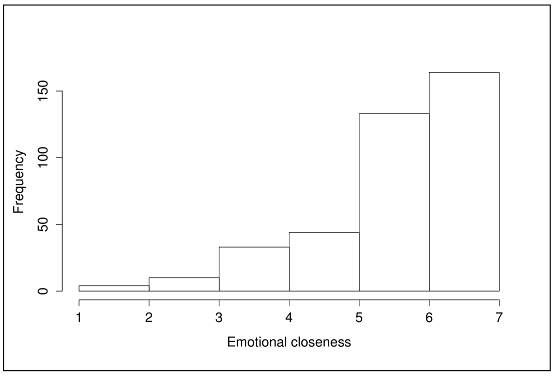


Figure 6: Overall distribution for grandparent's emotional closeness

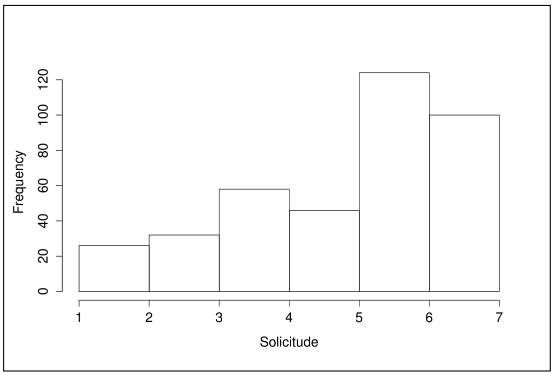


Figure 7: Overall distribution for grandchildren's solicitude

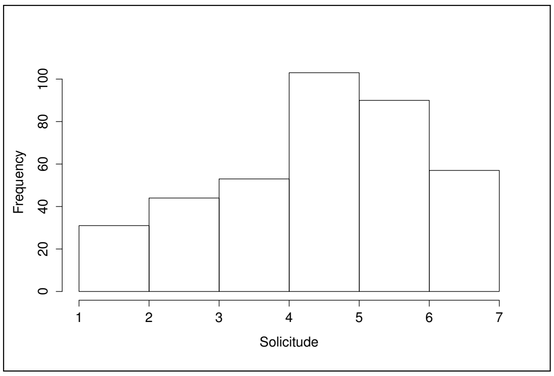


Figure 8: Overall distribution for parents' evaluation of solicitude

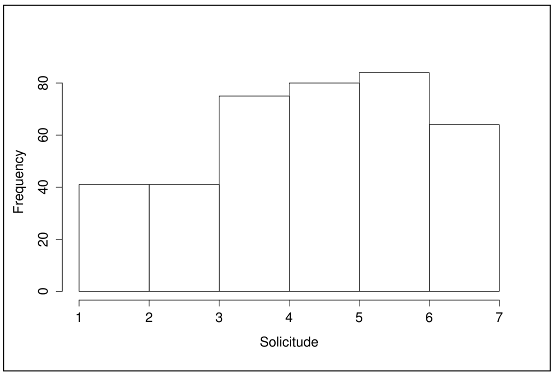


Figure 9: Overall distribution for grandparents' solicitude

shows the residual plot indicating the independence of error terms.

In order to analyze the main effects of sex of grandparents and their lineage as well as other categorical factors and interaction terms, post-hoc contrast derived from a priori hypotheses were calculated using the lsmeans package (Version 1.10-01). Least-Squares Mean (LSM) or population means are generalizations of covariate-adjusted means which are estimated for each category of interest. Differences between LSM, namely, Least-Squares Mean Difference (LSMD) are then tested against 0. Table 12 contains all LSMD for the main effects of the categorical variables and the interaction

Table 11

Linear mixed model coefficients for predicting global grandparental kin investment

	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Main factors						
Intercept (incl. MGM)	0.29	−0.21	$-0.42^{\dagger}$	0.14	0.02	−0.14
Reference (MGF)	-0.38^{***}	-0.37^{***}	-0.28^{*}	-0.31^{**}	-0.33^{***}	$-0.38^{(***)}$
Reference (PGM)	0.03	0.04	0.14	0.03	0.04	0.10
Reference (PGF)	-0.41^{***}	-0.38^{***}	$-0.23^{\dagger}$	-0.39^{**}	-0.40^{**}	$-0.62^{(**)}$
Resemblance	0.08^{*}	0.04	0.02	−0.01	0.01	0.01
Grandchildren factors						
Sex (male)		−0.09	−0.10	−0.11	−0.10	0.15
Birth order (middle)		$-0.26^{\dagger}$	$-0.25^{\dagger}$	$-0.28^{\dagger}$	-0.30^{*}	-0.33^{*}
Birth order (last)		−0.04	−0.04	−0.09	−0.05	−0.09
Grandparent factors						
Age difference		-0.02^{*}	-0.03^{**}	−0.01	−0.01	0.00
SES (medium)		0.79^{***}	0.75^{***}	0.77^{***}	0.68^{***}	$0.97^{(***)}$
SES (high)		0.72^{***}	0.84^{***}	0.96^{***}	0.80^{***}	$1.39^{(***)}$
Co-residence (separate)		-0.23^{*}	−0.08	−0.09	−0.09	0.08
Health Status		0.10†	0.13^{*}	0.04	0.01	−0.02
Parent-grandparent factors						
Maternal relationship quality			0.17^{***}	0.16^{***}	0.15^{***}	0.05
Paternal relationship quality			0.05	0.06	0.06†	$0.21^{(**)}$
Background (P urban & GP rural)			0.18	0.14	0.29†	0.39(†)
Background (P & GP urban)			−0.05	0.03	0.07	0.12
Educational difference			0.05	0.05	0.00	0.00
Family factors						
Distance				-0.14^{***}	-0.10^{*}	-0.10^{*}
Family Size				0.02	−0.03	−0.03
Provision (middle)				−0.02	0.02	−0.07
Provision (last)				-0.56^{***}	-0.31^{*}	-0.41^{**}
Interactions terms						
Ref. (MGF) x sex (male)						$0.22^{(*)}$
Ref. (PGM) x sex (male)						0.09
Ref. (PGF) x sex (male)						$0.60^{(**)}$
Ref. (MGF) x co-res. (separate)						$-0.38^{(**)}$
Ref. (PGM) x co-res. (separate)						−0.05
Ref. (PGF) x co-res. (separate)						−0.15
Ref. (MGF) x maternal relationship quality						$0.09^{(\dagger)}$
Ref. (PGM) x maternal relationship quality						$0.19^{(*)}$
Ref. (PGF) x maternal relationship quality						$0.18^{(*)}$
Ref. (MGF) x paternal relationship quality						$-0.09^{(\dagger)}$
Ref. (PGM) x paternal relationship quality						$-0.18^{(*)}$
Ref. (PGF) x paternal relationship quality						$-0.28^{(**)}$
Sex (male) x SES (medium)						−0.41
Sex (male) x SES (high)						$-0.72^{(*)}$
Ref. (MGF) x Background (P urban & GP rural)						0.04
Ref. (PGM) x Background (P urban & GP rural)						−0.29
Ref. (PGF) x Background (P urban & GP rural)						−0.25
Ref. (MGF) x background (P & GP urban)						0.20
Ref. (PGM) x background (P & GP urban)						−0.30
Ref. (PGF) x background (P & GP urban)						−0.13
Model parameters						
AIC	993.04	971.98	952.96	928.95	833.16	814.43
df	8	16	21	25	34	54
logLik	−488.52	−469.99	−455.48	−439.48	−382.58	−353.22
Chi^2 of likelihood-ratio-test		37.06^{***}	29.02^{***}	32.01^{***}	113.80^{***}	58.72^{***}
Adjusted R^2	.49	.53	.57	.63	.97	.97
Cohen's κ	5.27	8.58	8.75	14.74	14.74	33.06

Note. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; all metric variables are centered around the grandmean.

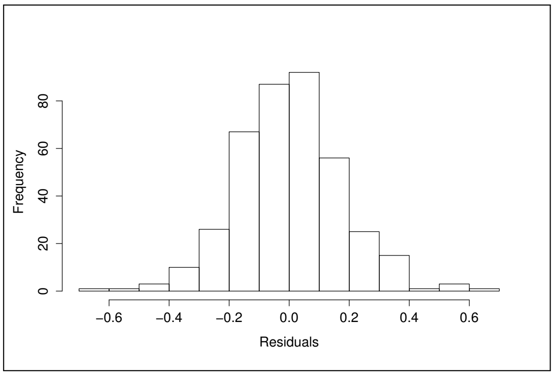


Figure 10: Distribution of residuals in the final model (Model 8)

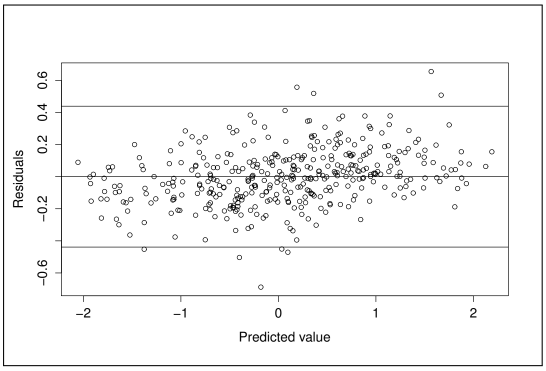


Figure 11: Residual Plot of the final model (Model 8)

terms which is described in the following section.

7.5. Analysis of Predictors

Analysis of the final model indicated a large main effect of sex of grandparents with grandmothers investing more than grandfathers, while there was no significant effect of grandparents laterality. LSMD were 0.42 (p < .001, SE = 0.06) and 0.10 (p = .380, SE = 0.12) regarding the sex- and laterality effect, respectively. The comparison between LSM of MGF and PGM revealed a significant difference of -0.31 (p = .012, SE = 0.12) favoring paternal grandmothers over maternal grandfathers. An additional analysis was carried out on the difference between PGM and MGF for the splitted sample of families where PGM had additional grandchildren via their daughters (N = 18) and families where this was not the case (N = 22). The LSMD of -0.08 was not significant (p = .609, SE = 0.16) in the case where PGM did not have additional grandchildren via their daughters, whereas it was highly significant with -0.64 (p < .001, SE = 0.19) in the case of PGM having additional grandchildren via their daughters.

There was no significant main effect for sex of grandchildren, however, contrast analysis of the interaction term sex of grandchildren and type of grandparent revealed a significant difference only for PGF, whereas there was no significant difference among the other three grandparent types. LSMD for the PGF was -0.37 (p = .041, SE = 0.18) favoring grandsons over granddaughters. Figure 12 depicts this situation. The found interaction partially supported SA-ZD theory as same-sex preference for paternal grandparents was highly significant (LSMD = 0.51, p < .001) when it was only marginal significant for the maternal side (LSMD = 0.22, p = .056).

Table 12

Post-hoc contrasts of factorial variables and interaction terms

	LSMD	*p*	*SE*	lower CI	upper CI
Main sex-effects					
Sex of grandparent (grandmother - grandfather)	0.42	< .001	0.06	0.30	0.54
Sex of parent [lineage] (maternal - paternal)	0.10	.380	0.12	−0.13	0.34
Sex of grandchild (granddaughter - grandson)	0.00	.989	0.13	−0.26	0.26
Specific comparison					
Maternal grandfather - paternal grandmother	−0.31	.012	0.12	−0.55	−0.08
Grandparent-grandchild interaction					
Maternal grandmother (granddaughter - grandson)	0.23	.188	0.17	−0.11	0.56
Maternal grandfather (granddaughter - grandson)	0.01	.941	0.15	−0.28	0.31
Paternal grandmother (granddaughter - grandson)	0.14	.457	0.18	−0.22	0.49
Paternal grandfather (granddaughter - grandson)	−0.37	.041	0.18	−0.72	−0.02
Other main effects					
Birth order of grandchildren (first - middle)	0.33	.046	0.16	0.01	0.64
Birth order of grandchildren (first - last)	0.09	.467	0.12	−0.15	0.32
Birth order of grandchildren (middle - last)	−0.24	.157	0.16	−0.55	0.08
Birth order of grandchildren (first and last - middle)	0.27	.077	0.15	−0.02	0.56
Socioeconomic status (low - medium)	−0.77	< .001	0.17	−1.10	−0.43
Socioeconomic status (low - high)	−1.03	< .001	0.21	−1.45	−0.62
Socioeconomic status (medium - high)	−0.27	.018	0.11	−0.62	0.09
Maternal relationship (parents - parents in-law)	−0.14	.057	0.07	−0.28	0.00
Paternal relationship (parents - parents in-law)	−0.19	.021	0.08	−0.34	−0.03
Parents background (rural - urban)	−0.17	.283	0.15	−0.46	0.13
Grandparents background (rural - urban)	0.07	.578	0.12	−0.17	0.30
Co-residence (together - separate)	0.06	.524	0.10	−0.13	0.26
Provision of grandchildren (first - middle)	0.07	.716	0.18	−0.29	0.42
Provision of grandchildren (first - last)	0.41	.011	0.16	0.10	0.72
Provision of grandchildren (middle - last)	0.34	.096	0.20	−0.05	0.74
Other interaction effects					
Low Socioeconomic status (granddaughter - grandson)	−0.38	.217	0.30	−0.96	0.21
Medium Socioeconomic status (granddaughter - grandson)	0.04	.741	0.12	−0.20	0.27
High Socioeconomic status (granddaughter - grandson)	0.34	.026	0.15	0.05	0.64
Grandmothers co-residence (together - separate)	−0.06	.607	0.11	−0.27	0.16
Grandfathers co-residence (together - separate)	0.18	.086	0.11	−0.03	0.40
Background (both rural) x (maternal - paternal)	−0.10	.567	0.17	−0.43	0.24
Background (parents urban) x (maternal - paternal)	0.19	.324	0.19	−0.18	0.56
Background (both urban) x (maternal - paternal)	0.22	.266	0.19	−0.16	0.59

Results concerning the perceived resemblance indicated a significant influence only for model 3 with an estimate of 0.08. Therefore, an increase or decrease of one point on the 7-point likert scale translates into an increase or decrease of 0.08 standard deviations on the outcome variable. This influence, however, disappeared in the following models. The average overall rating for resemblance was 3.02 on the 7-point likert scale (SD = 1.35), when it was 2.82 for MGM (SD = 1.26), 2.87 for MGF (SD = 1.26), 3.08 for PGM (SD = 1.46) and 3.33 for PGF (SD = 1.37). It is noted, that the pearson correlation between the perceived resemblance of grandparents with their grandchildren and the rated number of cuckcoo children in the population

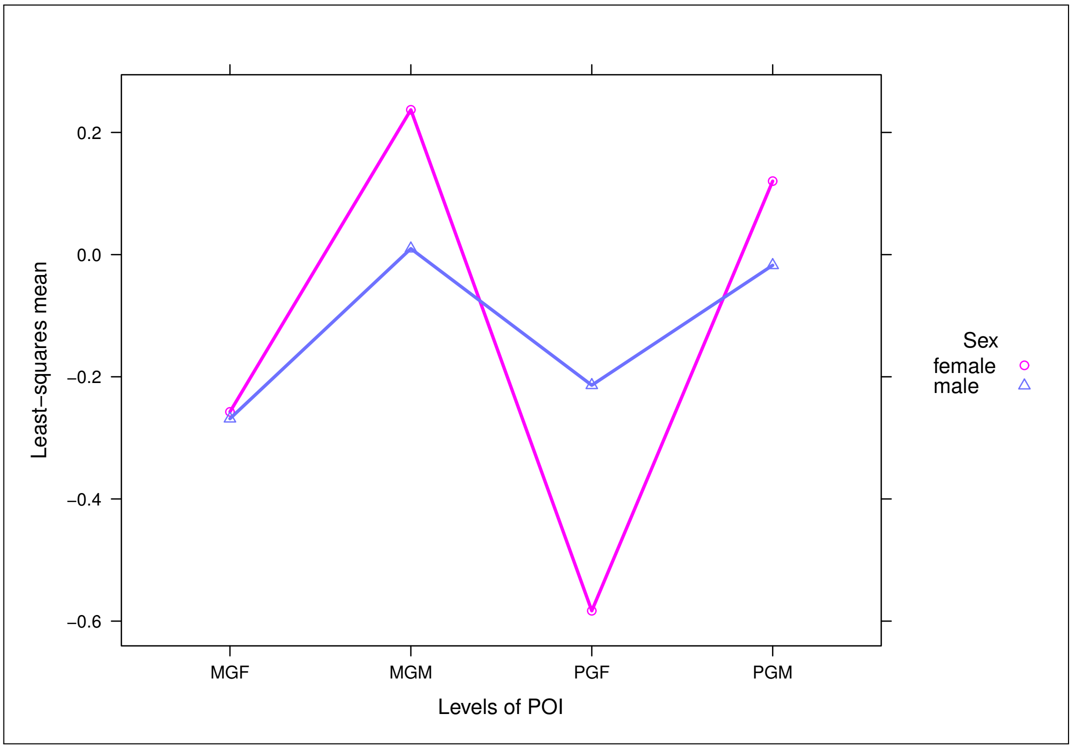


Figure 12: Amount of investment for type of grandparent by sex of grandchild

was -.11 (p = .054). This indicated that a higher perceived resemblance rated by grandparents is associated with lower paternity uncertainty of the population assumed by grandparents. Grandparents on average guessed that 64.13 cuckoo children out of 1000 (Mdn = 32.50, SD = 88.69, n = 120) exist in a population; the average guess by type of grandparent was: MGM 54.03 (Mdn = 20, SD = 82.73, n = 30), MGF 46.10 (Mdn = 27.50, SD = 53.39, n = 36), PGM 77.66 (Mdn = 50, SD = 90.31, n = 25), PGF 85.31 (Mdn = 50, SD = 113.62, n = 29). Grandparents' guesses were slightly higher than actual paternity uncertainty rates, which is in accordance with Voracek, Haubner, and Fisher (2008), whereas the comparison of grandmothers with grandfathers were not clearly in the same direction as reported by the same authors. Interestingly, when comparing means of resemblance for each type of grandparent, which are provided in Table 13, the order for the different types of grandparents was not in accordance with paternity uncertainty suggestions.

Regarding the birth order of grandchildren the LSMD between first and middle born was 0.33 (p = .046, SE = 0.16), between first and last born 0.09 (p = .467, SE = 0.12) and between middle and last born -0.24 (p = .157, SE = 0.16). Comparing first and last born against middle born resulted in a marginal significant LSMD of 0.27 (p = .077, SE = 0.15). Results, therefore, indicated a U-shaped trend of birth order of

Table 13
Mean resemblance for each type of grandparent

	MGM	MGF	PGM	PGF
Overall	2.82 (1.26)	2.87 (1.26)	3.08 (1.46)	3.33 (1.37)
Separated				
granddaughters	3.00 (1.29)	2.91 (1.25)	3.45 (1.48)	3.30 (1.30)
grandsons	2.64 (1.22)	2.82 (1.28)	2.71 (1.34)	3.35 (1.44)

Note. standard deviation appear in brackets.

grandchildren.

No main effect of grandparents' age in terms of age difference to grandchildren in question was determined in the final model. Still, before adding family factors in model 6 there was a significant negative influence in model 4 (β = -0.02) and model 5 (β = -0.04) which stayed insignificant in model 7 and 8. The reported mean age difference was 53.39 (SD = 6.36, Min = 37, Max = 71). It is interesting that age difference correlated highly positive with family size (r_p = .33 p < .001) and positive with distance (r_p = .10 p = .050), when family size and distance correlated negatively with each other (r_p = -.13 p = .008) which, however, remains unexplained.

Regarding the SES of grandparents there was a trend that grandparents with higher SES tended to invest more in grandchildren. Grandparents with a low SES had a LSM of -0.72 (SE = 0.20), with a medium SES had a LSM of 0.05 (SE = 0.11) when grandparents with high SES had a LSM of 0.31 (SE = 0.13). All differences were significant. Results on the interaction term of SES and sex of grandchildren revealed that grandparents with low SES tended to invest more in grandsons than granddaughters, whereas grandparents with high SES tended to invest more in granddaughters than grandsons, and grandparents with medium SES tended to not differentiate.

Analysis on co-residence of grandparents, at first, indicated a significant negative main effect in model 3, which became insignificant after adding parent-grandparent factors in model 4 and all subsequent models. Looking into the interaction term of co-residence and type of grandparent showed a marginal trend for separated grandfathers to invest less in their grandchildren (LSMD = 0.18, p = .086), when there was no difference for grandmothers. Likewise, there was a marginal positive main effect of health of grandparent in model 3 and a significant main effect in model 4 which disappeared after adding family factors in model 5. The mean health ratings was 4.14 (SD = 0.76) on the 5-point likert scale.

The main effects for maternal relationship quality was highly significant, positive in model 5, 6 and 7, whereas the estimate in model 8 was not (probably a distortion due to interaction terms). Similarly, the paternal relationship quality was not significant in model 5, 6 and 7 when it was marginally significant in model 8 (probably also distorted due to interaction terms). Both effects needed to be interpreted with post-hoc contrasts. LSM for the maternal relationship with their parents was 0.10 (SD = 0.04) when it was 0.24 (SD = 0.06) with their parents in-law resulting in an barley significant LSMD of -0.14 (p = .057). Likewise, LSM for the paternal relationship with their parents was -0.017 (SD = 0.05) when it was 0.17 (SD = 0.06) with their parents in-law resulting in an significant LSMD of -0.19 (p = .021). The results, therefore, indicated that the relationship quality of the parental generation with their parents in-law was relevant for the amount of grandparental investment provided than the relationship with ones own parents.

The results on the background of parents and grandparents indicated a marginal significant effect for parents that have moved to urban regions when they originally stem from a rural region. Post-hoc contrast indicated marginal differences between parents and grandparents living in urban as well as rural regions (LSMD = 0.20, p = .085; LSMD = 0.26, p = .098). Interestingly, grandparents had higher investment scores when the parental generation moved from a rural to an urban region, however, there was no significant difference between paternal and maternal grandparents stemming from rural or urban regions. Even though not significant, the estimates showed a slight trend in rural regions with paternal grandparents investing more than maternal grandparents, whereas in urban regions maternal grandparents tended to invest more than paternal grandparents.

No model had a significant effect for the educational difference between parents and grandparents. Likewise, there was no significant effect for the family size of grandparents. The logarithmized residential distance between grandchildren and grandparents, however, showed a significant negative impact on grandparental investment in all three models. The LSM estimate of -0.10 (SE = 0.03) indicated that the larger the distance the less grandparents invest.

With regard to the provision of grandchildren, the results indicated the least investment if the parental generation were the last ones providing grandchildren. LSMD between the provision of first and last as well as between middle and last were 0.410 (p = .011, SE = 0.16, 95% CI = [0.096; 0.724]) and 0.344 (p = .096, SE = 0.20, 95% CI = [-0.048; 0.736]), respectively, whereas there was no difference between first and middle ones (LSMD = 0.066).

7.6. Comparability of Information

This section contains the results on two interests. First, the comparability of information between grandchildren, grandparents and parents is provided. Second, an analysis with the two other investment measures - emotional closeness and solicitude - was carried out. Therefore, additional five linear mixed models with different dependent variables were calculated. It is important to note that the dependent variables, emotional closeness and solicitude, were not normal distributed in any of the models and, therefore, were not standardized. Instead, the dependent variables of the five models were kept in their raw format on a 7-point likert scale with different means and standard deviations. Therefore, interpretation and comparison of absolute LSMD between the first two and last five models should be made with caution.

It was intentioned to check whether results on the main effects of gender for all three generations differ depending on the generation asked, as well as between the additional items of emotional closeness and solicitude. To realize this, the structure of the final model 8 was used for all models, except for the interaction term of type of grandparent with background which was removed because it was not significant in the final model and the predictive power of the model stayed the same when model complexity and collinearity was reduced at the same time. Table 14 contains the estimates, fit-indices and post-hoc contrasts of the different models including a reduced model 8 for comparability. Table 15 shows the individual contributions of predictors.

First, it is notable that the correlation matrix of all dependent variables showed that all measurements were highly correlated with each other (see Table 14). The correlation coefficients between different measures were larger within one generation than between the generations. Measures obtained from grandchildren correlated higher with each other as well as measures from grandparents correlated higher with each other than measures from grandchildren did with measures from grandparents.

Another interesting fact was that scores from grandparents tended to be lower for the calculated investment score and the general solicitude rating, when emotional

Table 14

Linear mixed model coefficients for predicting grandparental kin investment

	Investment		Emotional closeness		Solicitude		
	Model 8r	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
	GC	GP	GC	GP	GC	P	GP
Main factors							
Intercept (incl. MGM)	−0.01	0.13	4.27$^{(***)}$	5.67$^{(***)}$	5.97$^{(***)}$	5.88$^{(***)}$	5.60$^{(***)}$
Reference (MGF)	−0.32$^{(**)}$	−0.32	−0.28	−0.13	−0.37$^{(\dagger)}$	−0.70$^{(***)}$	−1.20$^{(**)}$
Reference (PGM)	−0.04	−0.01	0.12	0.06	−0.31	0.13	−0.24
Reference (PGF)	−0.69$^{(**)}$	−0.51$^{(*)}$	−0.79$^{(*)}$	−0.23	−1.07$^{(**)}$	−0.39	−0.77$^{(\dagger)}$
Resemblance	0.00	0.08***	0.03	0.16***	−0.07	0.01	0.10*
Grandchildren factors							
Sex (male)	0.16	−0.27$^{(\dagger)}$	0.80	0.62$^{(*)}$	−0.05	−0.28	0.16
Birth order (middle)	−0.31*	−0.02	−0.39	0.03	−0.23	−0.09	−0.04
Birth order (last)	−0.08	−0.07	−0.02	−0.24*	−0.31†	−0.04	−0.10
Grandparent factors							
Age difference	0.00	0.01	0.01	0.01	0.00	−0.03*	0.02
SES (medium)	0.92$^{(***)}$	0.91$^{(***)}$	1.56$^{(***)}$	0.86$^{(**)}$	1.09$^{(**)}$	0.73$^{(**)}$	1.19$^{(**)}$
SES (high)	1.29$^{(***)}$	0.83$^{(**)}$	1.79$^{(***)}$	0.71$^{(*)}$	1.23$^{(**)}$	0.78$^{(*)}$	0.72
Co-residence (separate)	0.07	0.18	0.23	0.55$^{(*)}$	−0.05	0.07	0.31
Health Status	−0.02	−0.06	0.05	−0.01	−0.11	−0.02	0.10
Parent-grandparent factors							
Maternal relationship quality	0.07	−0.02	0.12	0.03	0.14$^{(\dagger)}$	0.30$^{(***)}$	−0.12
Paternal relationship quality	0.21$^{(**)}$	0.01	0.21$^{(\dagger)}$	0.18$^{(\dagger)}$	0.29$^{(*)}$	−0.06	−0.15
Background (P urban & GP rural)	0.26†	0.01	0.15	0.38†	−0.08	−0.35	0.21
Background (P & GP urban)	0.09	0.28†	0.12	0.22	−0.03	−0.08	0.14
Educational difference	−0.01	0.10†	0.15†	−0.03	0.06	0.00	0.08
Family factors							
Distance	−0.11**	−0.11**	−0.24***	−0.15**	−0.14†	−0.11†	−0.25**
Family Size	−0.02	−0.16	0.20	0.05	−0.14	−0.31	−0.13
Provision (middle)	−0.05	−0.33†	−0.23	−0.49*	0.02	−0.25	−0.73*
Provision (last)	−0.42**	−0.37**	−0.51*	−0.43*	−0.37	−0.53*	−0.54*
Interactions terms							
Ref. (MGF) x sex (male)	0.22$^{(*)}$	0.16†	−0.21	−0.01	−0.14	−0.01	0.16
Ref. (PGM) x sex (male)	0.08	0.14	−0.30	0.31	0.13	0.05	0.32
Ref. (PGF) x sex (male)	0.60$^{(**)}$	0.41**	0.32	0.08	0.28	0.03	−0.01
...	(further interaction terms were omitted for brevity)						
Post-hoc contrasts							
GP sex-effect (GM - GF)	0.42***	0.24*	0.53***	0.38**	0.74***	0.58***	0.80***
P sex-effect [lineage] (MG - PG)	0.05	0.08	0.33†	0.07	0.37†	0.10	0.19
GC sex-effect (GD - GS)	0.00	0.11	−0.12	−0.27*	0.16	0.17	−0.14
Specific: MGF - PGM	−0.37**	−0.16	−0.20	−0.31†	−0.37†	−0.48*	−0.61*
Interaction: MGM (GD - GS)	0.22	0.29**	−0.17	−0.17	0.23	0.18	−0.02
Interaction: MGF (GD - GS)	0.01	0.13	0.04	−0.16	0.37	0.20	−0.18
Interaction: PGM (GD - GS)	0.14	0.16†	0.13	−0.48**	0.10	0.13	−0.35†
Interaction: PGF (GD - GS)	−0.37*	−0.12	−0.49	−0.25	−0.05	0.150	−0.01
Model parameters							
Adjusted R^2	.97	.98	.92	.98	.96	.96	.97
Cohen's κ	29.15	29.15	29.01	29.15	29.01	29.47	28.92

Note. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; all metric variables are centered around the grandmean.

Table 15

ANOVA Table with Satterthwaite approximation for degrees of freedom

	Investment		Emotional closeness		Solicitude		
	Model 8r	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
	GC	GP	GC	GP	GC	P	GP
Main factors							
Reference	17.35^{***}	$2.26^{\dagger}$	6.61^{***}	3.40^{*}	14.47^{***}	13.38^{***}	8.81^{***}
Resemblance	0.04	14.10^{***}	0.35	22.21^{***}	2.11	0.03	5.02^{*}
Grandchildren factors							
Sex	0.00	$3.02^{\dagger}$	0.31	5.57^{*}	0.69	1.07	1.29
Birth order	$2.47^{\dagger}$	0.63	1.44	3.69^{*}	1.92	0.14	0.46
Grandparent factors							
Age difference	0.11	0.39	0.15	1.22	0.04	4.49^{*}	1.29
SES	15.24^{***}	7.20^{**}	7.69^{***}	1.32	5.86^{**}	6.95^{**}	3.28^{*}
Co-residence	0.50	0.00	0.01	2.28	$2.75^{\dagger}$	1.50	0.26
Health Status	0.23	0.87	0.28	0.01	1.54	0.09	0.66
Parent-grandparent factors							
Maternal relationship quality	21.67^{***}	$2.94^{\dagger}$	22.61^{***}	4.96^{*}	16.75^{***}	47.34^{***}	0.00
Paternal relationship quality	4.12^{*}	0.14	$2.77^{\dagger}$	0.44	2.13	0.56	0.05
Background	$2.56^{\dagger}$	$2.46^{\dagger}$	0.21	1.64	0.06	1.70	0.29
Educational difference	0.00	$2.76^{\dagger}$	$3.45^{\dagger}$	0.16	0.57	0.00	0.53
Family factors							
Distance	5.97^{*}	8.16^{**}	13.80^{***}	7.18^{**}	$3.69^{\dagger}$	$2.94^{\dagger}$	10.61^{**}
Family Size	0.03	1.61	0.82	0.05	0.32	1.23	0.31
Provision	4.09^{*}	4.43^{*}	2.25	4.12^{*}	1.06	$2.42^{\dagger}$	3.80^{*}
Interactions terms							
Reference x sex of GC	7.71^{***}	4.78^{**}	1.67	1.01	0.48	0.01	0.94
SES of GP x Sex of GC	3.26^{*}	4.43^{*}	1.46	6.28^{**}	0.24	0.52	$2.74^{\dagger}$
Reference x co-residence of GP	4.27^{*}	1.35	0.61	1.06	1.79	$2.43^{\dagger}$	1.66
Reference x maternal rls. quality	3.81^{*}	0.44	0.67	1.31	1.72	1.34	1.45
Reference x paternal rls. quality	2.68^{*}	1.19	2.81^{*}	1.09	$2.38^{\dagger}$	$2.33^{\dagger}$	$2.65^{\dagger}$

Note. F-values are depicted in the table; $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 16

Correlation matrix of dependent variables

		Investment		Emotional closeness		Solicitude		
		GC	GP	GC	GP	GC	P	GP
Investment	GC	1	.48	.64	.34	.70	.49	.34
	GP	.46	1	.30	.48	.370	.37	.63
Emotional closeness	GC	.62	.29	1	.32	.61	.33	.28
	GP	.36	.51	.30	1	.31	.23	.44
Solicitude	GC	.71	.38	.60	.31	1	.43	.33
	P	.50	.39	.33	.28	.45	1	.30
	GP	.35	.62	.28	.49	.36	.30	1

Note. All correlations are significant at .001; upper right triangle shows Pearson's product–moment correlations while the lower left shows Spearman's correlation coefficients.

closeness scores, on the other hand, were rated lower by grandchildren for every type of grandparent (see Table 10). Answers from grandparents regarding investment might be hold back as grandparents do not have a direct comparison with other grandparents' investment. But, no matter how much grandparents actually invested or at least thought having invested they felt very close to their grandchildren when grandchildren, on the other hand, had a different opinion of emotional closeness.

When comparing the three grandchildren models 8r, 10 and 12 with each other, some minor differences were found for the estimates of the predictors as well as for the specific post-hoc contrasts calculated afterwards (see Table 10). While the influence of distance was highly significant in model 8r and 10 it was only marginal significant in model 12. Providing the last grandchild was not significant in model 12 when it was significant in model 8r and 10. Only in model 8r, birth order of grandchildren was significant when it was not in model 10 and 12.

Regarding the LSMD of the post-hoc contrasts there was a highly significant effect for gender of grandparent in all three models. However, there was no significant effect for gender of parent (lineage); in model 10 and 12 it was marginal though. The specific comparison between PGM and MGF yielded no significant difference in model 10, a marginal difference in model 12 and a high significant difference in model 8r. The main gender effect of grandchildren was not significant in any of the three models, however, there was a specific difference for PGF in model 8r with grandsons reported to receive more investment from PGF than granddaughters reported. In model 10 and 12 none of the interaction contrasts reached significance although for some type of grandparents the absolute LSMD were larger than for others. With regard to the SA-ZD theory an interesting aspect was the positive LSMD for PGM in model 8r and the negative LSMD for PGF in model 10. Such a trend could indicate that PGM tended to be emotionally closer to and invest more in their granddaughters than their grandsons, whereas PGF tended to be closer to and invest more in their grandsons than their granddaughters. However, model 12 did not indicate a trend that supported SA-ZD predictions.

Interestingly, the comparison of the three grandparents' models 9, 11 and 14 depicted differences for the LSMD estimates, but also some major differences of the predictor variables (see Table 10). When in model 9 and 14 there was no main influence of the co-residence of grandparents there was a significant positive one in model 11 for emotional closeness. This means that separated grandparents rated their emotional closeness higher than grandparents who lived together, but looking into detail revealed that this was only the case for MGM. For grandparents the birth order of the last grandchild seems to be only relevant for emotional closeness.

The main effect for gender of grandparent was again significant in all three models. Likewise, there was no significant effect of lineage in any of the three models. However, there was a significant effect for gender of grandchildren in model 11 when there was no significant effect in model 9 and 14 with grandparents reported to be emotionally closer to granddaughters than grandsons. PGM and MGF did only significantly differ in model 14 with PGM reported to invest more than grandfathers. Interestingly, in model 11 the specific interaction contrast for PGM reached significance and marginal significance in model 14 which, surprisingly, was negative. According to this, PGM rated themselves emotionally closer to and to invest more in grandsons than granddaughters. In model 9, on the other hand, the interaction term was also marginal significant, but positive.

A comparison of the predictor's estimates of the grandparent models with those from the grandchildren models showed a major difference for resemblance which was significant in all grandparent models when it was not significant in any grandchildren models. Estimates for the provision of grandchildren were a bit different which was not looked into detail. There was a minor difference in the estimate of distance, which was only marginal significant in the grandchildren's model 12 when it was significant in all other five models.

Regarding the specific post-hoc contrasts there were some small differences between the models. The specific contrast between PGM and MGF were significant in some models when it was not in others, although the direction was always negative with PGM reported to invest more or be emotionally closer than MGF. Another notable difference was that LSMD for PGM was significant negative in model 11 when it was not significant but positive in model 10. A similar case was found in model 12 and 14, where the negative LSMD in model 14 was only marginal negative when in model 12 it was around zero.

The comparison of parents' information regarding solicitude, which is represented in model 13, with that of grandchildren's and grandparents' information, which are represented in model 12 and 14, yielded some differences for the predictors. Age difference was only significant negative in model 13. There was a difference for the main effect of maternal relationship quality which was highly significant positive in model 13 when it was only marginal positive in model 12 but not significant although negative in model 14. The main effect of paternal relationship quality was only significant in model 12. The effect of distance was marginal significant negative for model 13 and 12, whereas it was highly significant negative in model 14. LSMD of the specific contrasts were somehow comparable between all models. A minor difference was that the specific LSMD between MGF and PGM was only marginal significant in model 12 when it was significant in model 13 and 14, which in turn resulted in the lineage-effect in model 12 to be marginal significant when it was not in model 13 and 14.

During the comparison of the models a working hypothesis regarding the lineage effect, which was marginal in model 10 and 12, was formulated. The idea was that ratings on solicitude were influenced by emotional closeness. To check whether this was the case two additional models for the solicitude ratings (obtained by grandchildren and grandparents) were calculated with the same structure as model 12 and 14. Additionally emotional closeness was included as a confounder variable which was controlled for. In both models only the specific post-hoc contrast for sex of grandparents were to discuss which are presented in Table 17. In model 12.2 and 14.2 the difference between maternal and paternal grandparents stayed insignificant which would support the prior working hypothesis. However, this did not explain why there was no effect of lineage in the emotional closeness model 11 but in model 14 before.

Table 17
Post-hoc contrasts

	Model 12.2 GC	Model 14.2 GP
Post-hoc contrasts		
GP sex-effect (GM - GF)	0.51^{***}	0.75^{***}
P sex-effect [lineage] (MG - PG)	0.20	0.07
Specific: MGF - PGM	$-0.31^{\dagger}$	-0.67^{**}

Note. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

8. Discussion

The results of the empirical survey confirmed the frequently published effect of sex of grandparent which basically states that grandmothers invest more in their grandchildren than grandfathers due to social engendered roles of women. In contrast, however, findings suggested that there is no general effect of lineage of grandparents as opposed to the initial findings from Euler and Weitzel (1996) and more recent findings from Danielsbacka and Tanskanen (2012). After and even before controlling for all relevant factors, maternal and paternal grandparents' investment were not significantly different. Thus, full support is given to the statement by Voracek, Tran, and Fisher (2010) according to whom laterality effects are simply overstated and most likely do not exist.

Even the suggestion of Pashos (2000) according to which lineage effects vary depending on the background of grandparents was not supported by the data. However, there appears to be a more complex situation regarding the background of grandparents. The model suggested that the background of the parental generation also needs to be taken into account. The different combinations of parent-grandparent backgrounds need to be looked into detail in further research.

However, because there was no lineage effect in the present research, investment from PGM was generally higher than that of MGF, which was especially the case when paternal grandmothers had additional grandchildren via their daughters as opposed to predictions from preferential investment theory. The interesting case of no difference between MGF and PGM when the later had no additional grandchildren via their daughters totally contradicts this theory, which excludes preferential investment theory in the discussion of possible explanations.

At this point, the data only supports the kin-keeper theory or at least the fact that women tend to invest more than men, when on the other hand sex-specific reproduction theory, preferential investment theory and paternity uncertainty theory gains no support. However, the perceived resemblance, which is supposed to indicate paternity uncertainty, seems to be an important factor for investment when grandparents are asked. Surprisingly, however, the order of perceived resemblance between the different types of grandparents was not conform with the order suggested by paternity uncertainty theory. In fact, the more similar grandchildren were perceived the more investment they got, whereas it is conflicting that paternal grandparents, for example, perceived their grandchildren more similar than maternal grandparents. Because maternal grandfathers did not invest more in their grandchildren than paternal grandmothers, the suggestions from sex-specific reproduction strategies are not supported.

A general methodical note for the comparison of PGM and MGF is that the difference between them simply represents the difference between the two main effects of sex of grandparents and lineage and does not yield additional information. In contrast, the difference between the two grandparents ignores the absolute effect sizes of both main effects and it is, therefore, important to note that it makes very little sense to look at these specific differences without considering the size of both main effects.

By additionally considering the sex of grandchildren as a relevant factor, which is important for testing the more novel theories of chromosomal selection, the results were inconsistent for the different measures and the different generations. The interpretation of those results, however, is difficult. Although not constantly significant MGM, for instance, tended to invest more in granddaughters than grandsons but seemed to be emotionally closer to grandsons than granddaughters. PGF, however, seemed to invest more in grandsons and also were emotionally closer to them than to granddaughters. Paternal grandmothers' investment in granddaughters was higher than in grandsons which, however, was not significant. Interestingly, with regard to emotional closeness granddaughters indeed stated that they felt closer to PGM than grandsons but paternal grandmothers stated the complete opposite which is not explained by any of the theories and remains open for discussion. The general investment item solicitude showed a similar picture for PGM reporting a marginal preference for grandsons. The idea that general investment is superimposed by the perception of emotional closeness was supported as the incorporation of emotional closeness as a confounder resulted in a decrease of this preference.

Results obtained from the grandchildren's perspective of grandparental kin investment and emotional closeness, but not from solicitude, support SA-ZD theory as the comparison of same-sex preference between grandparents and grandchildren were higher for the paternal side than the maternal side. However, results obtained from the grandparent's and the parent's perspective does not support this theory. From the grandchildren's perspective the same-sex preference was highest for the PGF, which was also more consistent than the other same-sex preferences. Interestingly, this does support the sex-chromosomal selection idea, but in a way that links altruism more to the Y gonosome, which further highlights the traditional transmission of valuables from fathers to sons and their sons.

It is noticeable that the method of calculating differences between LSMD and comparing them with each other does not seem to be the correct way to examine the particular predictions of SA-ZD theory all other grandparent-grandchildren interactions are not considered or corrected for. In this research, however, this was the only possibility. Alternative statistical methods for testing this theory should be considered in future research.

The obtained data from the three different generations yielded the same results for sex- and lineage-effects of grandparents, whereas differences concerning specific interactions and the predictors were present. The individual contribution or explanatory power of predictors varied tremendously between information of different generations. Although results between the generations were comparable, however, not identical, it seems that the different generations use different cues to conclude the amount of investment provided. For grandparents the perceived resemblance and the distance to their grandchildren were the major indicators for the amount of grandparental investment when for the parental generation the relationship quality of the mother with the grandparental generation was the major indicator. For grandchildren, however, the maternal relationship quality and the socioeconomic background of grandparents seemed to be the most relevant. It is surprising that the maternal relationship quality was a major predictor for grandchildren's and parents' perceived grandparental kin investment, however, it was almost not relevant from grandparents' perspective.

The main effects of sex of grandparents, parents and grandchildren were similar between the different grandparental kin investment measures, however, detailed results did differ. Because emotional closeness and solicitude ratings were not normal distributed, the adequacy of results from models that used those dependent measures was not given. The underlying work tried to overcome problems of limitedness of single items by integrating different items into a global investment measure, which even more represents the definition of investment.

It turned out that there are at least three facets underlying the investment structure, which might be even further sub-divided, matching the proposition of the six facets proposed by Mansson (2012). However, the two immaterial facets (*non-verbal interaction* and *verbal interest and support*) were depicted by the six items (each) very good. The two items for the material facet (*unexpected presents*) were reliable too but contributed only about a fifth to the global investment measure, which seem not representative. It is open for discussion, whether the assembled questionnaire of this work is sufficient, efficient and fair enough and what items can be included in future to cover an even wider range of the investment spectrum.

9. Conclusion

The present diploma thesis makes several contributions to the clarification of differential grandparental kin investment due to the exemplary survey design. With the provision of a grandparental kin investment definition, an improved operationalization of measure by taking multiple aspects into account and by implementing all relevant influential factors in the analysis, the reevaluation of differential grandparental kin investment stands out of all preceding researches. The biggest advantage of the survey design is that not only all four grandparents were implemented, in order to control for exposure differences, but also the mandatory availability of grandchild-siblings with opposite-sex, which made it possible to test specific predictions from SA-ZD theory more accurately.

Strong support was given to the well documented effect of sex of grandparent with grandmothers generally investing more than grandfathers. More importantly, strong evidence against the existence of a laterality effect was provided, which rules out some theories competing for the explanation of DGKI. In the end, the social scientific theory of female kin-keeper is the only theory completely in accordance with the results. Yet, sex chromosomal selection theories are still promising as same-sex differences were found in some models, specifically for paternal grandparents.

Future research need to consider and implement the fact that investment consists of different aspects and that the perception of grandparental kin investment is different for each generation. Although it is not clearly which generation might depict actual grandparental kin investment more objectively, the grandchildren's reference seems more suitable for the analysis. Grandchildren can balance the investment of all four grandparents at once while for a grandparent it is hard to align their perception with those of the other grandparents resulting in different standard reference points for each one. The parents' view also seems not optimal as parents overstate the influence of their own, especially the maternal relationship quality with the grandparental generation.

In future research such a balanced design can be adapted to the related research strain of aunts and uncles, which was previously incorporated by some authors (e.g., Salmon, 1999; Hoier et al., 2001; Pashos & McBurney, 2008; Tran et al., 2009), when others investigated this family relationship separately (e.g., Gaulin et al., 1996; McBurney et al., 2002). However, due to the limitedness of resources and the complexity of the survey design (with respect to a diploma thesis) the investigation of aunts and uncles was left aside. A balanced design with similar preconditions (i.e. all eight matrilateral/patrilateral-aunt/uncle-niece/nephew dyades need to be present for a participant) would be optimal to confirm or invalidate the irrelevance of paternity uncertainty for kin investment as well as laterality differences. But, before research on differential grandparental kin investment should be continued, an agreement on the definition of grandparental kin investment and a consistent derived operationalization needs to be made; comprising not only one item. It is also crucial to discuss statistical aspects for the analysis of such data as specific cross-level interactions are predicted for some types of grandparents, but need also to be adjusted for the other combinations.

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List of Abbreviations

CFI	Comparative Fit Index
DGKI	differential grandparental kin investment
GC	grandchildren
GD	granddaughter
GLM	General Linear Model
GF	grandfathers
GM	grandmothers
GP	grandparents
GS	grandson
IBI	interbirth intervals
KMO	Kaiser-Meyer-Olkin factor
LSM	Least-Squares Mean
LSMD	Least-Squares Mean Difference
LMM	Linear Mixed Model
MG	maternal grandparents
MGF	maternal grandfathers
MGM	maternal grandmothers
NNFI	Non-Normed Fit Index
P	parental generation

PG	paternal grandparents
PGF	paternal grandfathers
PGM	paternal grandmothers
RMSEA	Root Mean Square Error of Approximation
SA-ZD	sexually antagonistic zygotic drive
SD	standard deviation
SES	socioeconomic status
SRMR	Standardized Root Mean Square Residual

List of Figures

List of Tables

A.1. Abstract (English)

With varying findings on differential grandparental kin investment various social scientific and evolutionary-based theories compete for their explanation. Different methods were used in previous research summarized in this work. In a three generational sample of 40 families including grandchild-siblings with opposite sex, both parents and all four grandparents allowed to analyze sex-effects for all generations and their cross-level interactions. Retrospective ratings on a multi-aspect questionnaire indicated a main effect for sex of grandparent, while no effect of their lineage respectively the parent's sex and no direct effect of sex of grandchildren was found. Only the kin-keeper theory is supported fully, but the sex-chromosomal selection theories, especially sexually antagonistic drive theory remain of interest as some type of grandparents preferred specific grandchildren over others.

A.2. Abstract (German)

Das Forschungsfeld der diskriminativen Fürsorglichkeit von Großeltern hat unterschiedlicheste Befunde hervorgebracht um deren Erklärung verschiedene sozialwissenschaftliche und evolutionärpsychologische Theorien konkurrieren. In dieser wissenschaftlichen Arbeit wurden verschiedenste Forschungsansätze der bisherigen Forschung miteinander verbunden. Mit Hilfe einer Stichprobe von 40 Familien, einschließlich gegengeschlechtlicher Enkelkinder, beiden Elternteilen und allen vier Großeltern, wurden Geschlechtseffekte der Generationen und deren Interaktionen untersucht. Die retrospektiven Beurteilungen aller Generationen haben den bereits vielfach replizierten Geschlechtseffekt der Großeltern eindeutig nachgewiesen. Die Untersuchung konnte jedoch keinen Geschlechtseffekt der Eltern bzw. der großelterlichen Linie sowie keinen direkten Geschlechtseffekt der Enkelkinder aufzeigen. Lediglich die Kin-Keeper Theorie erfährt vollständige Unterstützung durch die Daten. Theorien zur Geschlechtschromosomenvererbung bleiben weiter interessant, da sich einige gleichgeschlechtliche Präferenzen gezeigt haben.

A.3. Curriculum Vitae

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Name	Felix Deichmann
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Education	
2008 – Present	Diploma Programme psychology at University of Vienna, Austria
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1992 – 2006	general school education
Community service	
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