Why Care?

The impact of ancestral grandparental investments on caregiving and health today

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By
Sonja Hilbrand, B.Sc., M.Sc.
from Zürich, Switzerland

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Universität Basel

Supervisors Dr. David A. Coall[1,2]
Prof. Ralph Hertwig[3]

Oral examination board:
Examiner 1: Prof. Dr. Rui Mata[4]
Examiner 2: Prof. Dr. Ralph Hertwig[3]
Chair: Prof. Dr. Alexander Grob[4]

[1] Edith Cowan University, School of Medical and Health Sciences, Australia
[2] University of Western Australia, School of Psychiatry and Clinical Neurosciences, Australia
[3] Max Planck Institute for Human Development, Center for Adaptive Rationality, Germany
[4] University of Basel, Faculty of Psychology, Switzerland

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Dean Prof. Roselind Lieb

This framework is based on four manuscripts (appendices A-D) which are licensed as follows:

Manuscript 1. Research article with supporting information and author's comment

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Manuscript 2. Research article with supporting information

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Manuscript 3. Research article with supporting information

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Manuscript 4. Book chapter

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Statement of Originality

I, Sonja Hilbrand, hereby declare the following:

(i) This cumulative dissertation is my own account of research. It consists of four manuscripts, three published and one submitted for publication.[1] All collaborative researchers, references, and funding sources are declared in the manuscripts. Author contributions are declared as follows: For manuscripts 2 and 3 I am first the author and was primarily responsible for the ideas, data acquirement from the external database (BASE), data preparation and analyses, and writing of the manuscripts. For manuscript 1, I was primarily responsible for data acquirement from the external database (SHARE), data preparation and analyses, writing the method and result sections (including supporting information). I helped editing the whole of manuscript 1. Regarding the author's comment on manuscript 1, I conducted the analyses and wrote the comment. Manuscript 4 is a book chapter, which I have contributed to by partially writing and editing the text.

This characterisation of all my contributions is in agreement with my co-authors' views.

(ii) I only used the resources indicated.

(iii) I marked all citations.

(iv) The content of this dissertation has not been previously submitted, either in whole or in part, for a degree to any other university or other institution.

Aarau, 16.12.2016

Sonja Hilbrand

[1] In order to enhance reader's convenience, the manuscripts reported in this framework may slightly differ from their original or published versions. Adaptions had to be made in terms of page numbers, and position or layout of text, tables, and figures. The reference and layout formats differ among the manuscripts due to submission reasons. This framework is written in British English but the manuscripts are written either in American or British English.

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“If empathy and understanding develop only under particular rearing conditions, and if an ever-increasing proportion of the species fails to encounter those conditions but nevertheless survives to reproduce, it won’t matter how valuable the underpinnings for collaboration were in the past. Compassion and the quest for emotional connection will fade away as surely as sight in cave-dwelling fish.”

Sarah Blaffer Hrdy, 2009, p.293

Abstract

Why and how do humans in industrialised societies provide mutual care within and beyond the family? How does caregiving affect older helpers in Europe today? Examining these questions is important because family structures are rapidly changing and life expectancy has increased substantially in 21st century Europe. These demographic changes have often been designated as risks or burdens to society, especially in terms of health care. However, studying our evolutionary roots provides an out-of-the-box perspective that could help uncover social and health potentials lying dormant in these demographic changes.

In this framework, pathways are examined through which ancestral grandparental caregiving may have evolved from caregiving within the family to care provided well beyond biological relatedness. Moreover, it is investigated whether biological relatedness is still relevant in caregiving in contemporary European families. In addition, social and health benefits for older European helpers are explored. Throughout, perspectives from evolutionary biology, sociology, and psychology are linked, showing their complementary nature.

Three empirical research articles and one book chapter are comprised in this framework. The first article shows that biological relatedness between grandparents and their grandchildren was an independent predictor of caregiving levels in industrialised Europe. Equally important, a wide range of socioeconomic factors impacted grandparental care, pointing to the value of an interdisciplinary approach. The second article reviews evolutionary theorising about how the capacity for mutual care within and beyond the family may have evolved in the human species at an ultimate level. In addition, empirical analyses revealed that moderate amounts of help provided within and beyond the family enhanced the helper's longevity independent of prior health, age, support received, and a range of socioeconomic characteristics. The third article illustrates that the association between helping and longevity was partially mediated by health at a proximate level. Simultaneously, helping remained an independent predictor for longevity. Again, a wide range of covariates was controlled for, including prior health and various socioeconomic characteristics. The book chapter emphasises the new niche of grandfather involvement in childcare. This research area has long been ignored in the literature, but may illuminate valuable resources for contemporary families undergoing structural changes.

Overall, these findings suggest that our evolutionary inheritance of cooperation is still traceable in contemporary Europe and that there are good reasons to mindfully and actively engage in prosocial behaviour. Mutual care is not only beneficial to our personal health at an old age, it is crucial to further evolve as compassionate human beings into the future – provided our species will survive that long.

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1. Introduction

Mutual care among individuals of the human species cannot be taken for granted. It has evolved over millions of years and needs to be continuously expressed or it may be lost in the future (Hrdy, 2009). More specifically, receiving affectionate care at a young age is important to be able to provide it to others later in life, thus enabling the transmission of this behavioural trait into future generations. Mutual care is defined here as the ability to provide affectionate care to others, based on the experience of being cared for by others in the past. In investigating mutual caregiving, some questions are poorly understood. For example, why is the capacity for mutual care so well developed in our lineage (compared to other primates) and how is it expressed in families living in industrialised societies today? How does caregiving affect the health of older care providers? How do socioeconomic factors interplay with both, the disposition to provide care and its potential effects on the provider, specifically in terms of longevity and health? In this framework, these questions are addressed focusing on older adults in contemporary Europe. Next, it is explained why examining these questions and the focus on older adults is important.

In ageing societies, like in Europe, the increase of overlapping lifespan between generations is a unique aspect of human history (Uhlenberg, 1996). On the one hand, increased years of shared lives may demand substantial resources from the so-called middle generation potentially caring for frail parents and simultaneously raising their own children (Attias-Donfut, 1995). In addition, increased female participation in the labour force, divorce rates, and mobility alter family structures to which not only individuals have to adapt personally, but societies as a whole (e.g., political). These demographic changes may impose pressure on intergenerational relationships. On the other hand, the extended overlap of lifespan and expansion of the family (e.g., to non-biological family members after divorce) broaden opportunities for the older generation to transfer quality time, values or money to the younger generation. These transfers may substantially improve the latter group’s success and strengthen mutual bonds crucial to the health of all generations. Investigating caregiving within and beyond the family in aging populations may shed light on potential social and health benefits lying in current demographic changes.

Since social interactions play an important role in humans’ wellbeing (Tun, Miller-Martinez, Lachman, & Seeman, 2013) and healthy aging (Carstensen, 1995), they are relevant to social policy making, particularly in terms of health care. Engaging in social interactions may not only contribute to healthy aging, but to postponing health-related declines (e.g., cognitive abilities or functional health). These declines become most salient with approximating death (Gerstorf, Ram, Lindenberger, & Smith, 2013; Kleemeier, 1962) and during that time they are most likely to cause high personal and health care costs (see end-of-life costs, Breyer, Costa-Font, & Felder, 2010). End-of-life costs are inevitable, but encouraging older adults to have a socially engaged life style may decrease health care expenditure before end-of-life costs occur. Thus, the focus on care provided by older adults may illuminate valuable public health targets. In previous work, the older generation was typically regarded as a burden (see Bengtsson, 2010; Christensen, Doblhammer, Rau, & Vaupel, 2009), while in this framework they are explored in terms of their underestimated contribution to public health.

Investigating caregiving is entering an interdisciplinary field. Several disciplines (e.g., evolutionary biology, sociology, and psychology) have accumulated substantial amounts of knowledge about why and how humans do care for each other but these accounts largely co-exist side by side. Moreover, misconceptions of theorising often lead to competitive confrontation rather than complementary approaches. Calls for interdisciplinary research have been made (Coall & Hertwig, 2010) and recently they have been echoed (e.g., Danielsbacka, 2016, Kurzban, Burton-Chellew, & West, 2015). In order to support this interdisciplinary effort, different terms used for caregiving across the disciplines in question are explained next.

1.1 Different disciplines, different terms

There are multiple ways to describe and measure human caregiving and this may be the main starting point for the discord between disciplines. For psychologists and sociologists, the term grandparental ‘investment’, for example, may sound very odd and evoke some kind of inner resistance at first. Quite an effort is needed to understand that this term in fact is not so different from what social sciences may call grandparental ‘caregiving’. A common understanding between disciplines is imperative in order to constructively joining research forces. Therefore, terms referring to caregiving across disciplines and their use in this framework are described below.

Grandparental investment. This term is usually used by evolutionary biologists or anthropologists and emphasises the notion that grandparental caregiving comes with some degree of cost for grandparents. For example, a grandmother in a foraging society providing food for her daughter’s child had to make a certain effort in terms of her own resources (i.e. she could have eaten the food herself). In turn, the helping behaviour enhances her **inclusive fitness** (Hamilton, 1964). Inclusive fitness refers to the transmission of a person’s genes into future generations via the person's own actions and those of kin partially sharing these genes (de Waal, 2008). Thus, the birth and rearing of a (grand)child is an investment into the future survival of one's lineage and any support given to descendants (e.g., food, care, money) increases their chance of surviving and successfully reproducing (even after the (grand)parent has died and thus is not aware of these benefits). However, in industrialised societies, inclusive fitness may not be measured quantitatively in number of surviving descendants anymore, but in less tangible measures such as social competence or educational achievements of (grand)children (for a detailed review see Coall & Hertwig, 2010, 2011).

Grandparental caregiving, grandparenting, childcare provision. These terms are likely to sound familiar to researchers from the social sciences. In this framework they refer to the definition given by Glaser, di Gessa, and Tinker (2014) meaning the time spent looking after a grandchild regardless of his/her age. That includes, for example, meeting up with a grandchild 25 years of age.

Helping behaviour, supporting others, prosocial behaviour. In this framework, any human behaviour relating to the provision of care or support (e.g., instrumental, financial or emotional) is specified under these terms, independent of disciplines. They include support given to family and non-family members alike, if not stated otherwise.

When investigating caregiving among humans in an interdisciplinary field, it is not only necessary to comprehend the different terms used, but also to be familiar with the theories applied across disciplines. Therefore, an introduction into their theoretical backgrounds is presented next.

1.2 Different disciplines, different theories

Key concepts used to study caregiving across disciplines, specifically relevant to this framework, are briefly described (see also Carstensen, 1995; Coall & Hertwig, 2010; Danielbacka, 2016; Ebner, Freund, & Baltes, 2006).

1.2.1 Evolutionary perspective: Life history theory

The life history theory seeks to understand human behaviour in relation to specific environments by examining how the timing of distinct life phases and investment patterns (e.g., reproduction, grandparental investment and senescence) have been shaped by evolutionary forces. Predictions made are mainly based on the idea of inclusive fitness. Questions of interest are, for instance, which selective mechanisms have favoured women in the past to stop being able to reproduce themselves long before death and instead invest their resources in their already born descendants (e.g, provision of food and care)?

Within the life history theory framework, the **grandmother hypothesis** proposes that menopause and human longevity evolved adaptively (Hawkes, O'Connell, & Blurton Jones, 1997; Hawkes, O'Connell, Blurton Jones, Alvarez, & Charnov, 1998; Sear & Coall, 2011. For alternative views on menopause, see Peccei, 2001; Voland, Chasiotis, & Schiefenhövel, 2005; for alternative views on human longevity, see embodied capital model, Kaplan, Hill, Hurtado, Lancaster, & Robson, 2001). That is, the early cessation of female self-reproduction offered ancient grandmothers the opportunity to help raise their grandchildren. The provision of help in turn improved the menopausal women's own reproductive success with less risk (childbearing is costly and risky, especially an older age). Thus, helping grandmothers enabled their children to have more surviving grandchildren at shorter birth intervals which increased the grandmothers' inclusive fitness. Broadly speaking, any support given from a (grand)parent to a (grand)child increases the supporter's inclusive fitness (Trivers, 1972). Moreover, the longer these helping grandmothers were alive, the greater the benefits for their descendants. In sum, the evolutionary literature suggests that ancient grandparenting may have been modified into a fundamental mechanism that has steadily increased human longevity for both women and men (Hawkes & Coxworth, 2013; Kim, McQueen, Coxworth, & Hawkes, 2014).

Just as other species, such as many birds, humans are suggested to have evolved as **cooperative breeders** (Hrdy, 1999). That is to say, childrearing (which takes a remarkably long time in humans compared to other primates) is not exclusively mother-centred and infants have the best survival rates when they are cared for by several dedicated people in addition to the mother (and father). Prehuman and early human mothers may have had even more helpers available (Hrdy, 2009). So-called **allomothers** – men who thought they might have been the fathers, great-aunts, and older half-siblings – they would all have had their inclusive fitness enhanced by helping mothers with childrearing. This is one reason why the roots of human cooperation are suggested to have evolved within kin groups (see **kin selection theory**, Hamilton, 1964). Recent evidence using computational modelling suggests that contemporary humans still bias their willingness to cooperate with others according to whether or not they are perceived as kin (Hintze & Hertwig, 2016). The authors found that the ability to detect kin, not only evoked behaviour beneficial to kin members, but also enabled the development of generosity towards non-kin individuals. Furthermore, human newborns have impressive innate abilities to motivate any older person to engage in caregiving (e.g., crying or imitation of facial expressions). This may be one reason why people not genetically related to a child still provide care (Hrdy, 2009). Furthermore, seeing another person in pain or need (see de Waal, 2008) immediately activates neural networks triggering us to engage in prosocial behaviour (Brown & Okun, 2014). These neural networks may have evolved ultimately on the basis of the evolutionary advantage of cooperative breeding, but have subsequently generalised over thousands of years into the capacity for mutual care well beyond the family. This hypothesised expansion from caregiving within kin groups to non-kin and potential consequences on longevity and health are further explored in section 2.2 (for more details, also see Brown, Brown, & Preston, 2011; for alternative views on cooperation towards non-kin, see Riehl, 2013).

Next, the meanings of **ultimate** and **proximate mechanisms** are briefly explained. This distinction is crucial to understand evolutionary theorising. Definitions are drawn on de Waal (2008) stating that ultimate mechanisms refer to why and how a specific behaviour evolved over thousands of generations. They are typically related to inclusive fitness benefits. For example, cooperative breeding assigned a fitness benefit to those kin groups who practiced it. Thus, cooperation evolved as an ultimate foundation of human behaviour over thousands of generations. Proximate mechanisms refer to how immediate situations trigger specific behaviour or consequences within an individual's lifespan. They include learning, physiology, and emotions which are more typically the domains of the social sciences. As an example, seeing someone in pain or need evokes empathy that proximately enhances the chance that prosocial behaviour is actually carried out and not suppressed. Why empathy evolved in the first place would again refer to an ultimate mechanism. Thus, ultimate and proximate mechanisms are distinct concepts, yet behaviour is linked to both.

Other evolutionary concepts used in this framework play a less central role. Nevertheless, they merit some attention because they are important to understand the evolutionary arguments applied later in section 2.

Sex differences in reproduction strategies. Humans are one of the few mammalian species where paternal solicitude occurs at all. However, even when (grand)fathers are explicitly considered to be of help in raising children, like among Aka Pygmies (Hewlett, 1991), the level of paternal care pales in comparison to maternal care. Moreover, despite high fertility rates of human females compared to other mammals (Sear & Mace, 2008), a female's reproductive strategy maximises her inclusive fitness by devoting high levels of investment in relatively few children. Whereas a male's strategy for reproductive success, due to higher reproductive potential, is maximised by competing for additional mating opportunities (Symons, 1979), which makes paternal investment in his children more facultative (Euler & Michalski, 2007). In industrialised societies, however, having fewer but high quality offspring has become more important than ever before. Therefore, fathering and grandfathering may provide contemporary families with important resources contributing to the younger generation's success, for instance, better educational achievements that lead to better job opportunities later in life.

Paternity uncertainty. The degree of relationship certainty is another factor known to moderate (grand)parental investment (Euler & Weitzel, 1996). A mother can be sure that she shares a given gene with each of her children with a probability of .5. Unless there is a DNA test, a father does not have the same degree of certainty that his putative offspring actually shares his genes, even in societies claiming monogamous mating. According to evolutionary theory, mothers are therefore inclined to invest more than fathers.

Lineage. Combining the mind-set of both, sex-specific reproduction strategies and paternity uncertainty, suggests that grandparents would be expected to invest more in grandchildren via their daughters (maternal grandparents) than via their sons (paternal grandparents).

Biased grandparental investment. Using the same combination of sex-specific reproduction strategies and paternity uncertainty leads to a testable pattern of biased grandparental investment, meaning the maternal grandmother invests the most, followed by the maternal grandfather, paternal grandmother, and paternal grandfather. This pattern has been extensively studied and replicated across a wide range of measurements (e.g., caregiving, financial transfer, emotional closeness) and societies such as foraging traditions as well as in industrialised countries (Bishop, Meyer, Schmidt, & Gray, 2009; Coall, Meier, Hertwig, Wänke, & Höpflinger, 2009; Danielsbacka & Tanskanen, 2012; Euler & Weitzel, 1996; Pollet, Nettle, & Nelissen, 2007; Sear & Mace, 2008).

In sum, an evolutionary perspective offers a range of testable explanations as to why humans provide care to each other, but it has its limits. The influence of confounding factors often is neglected. For instance, the caregiver's health, personal values or welfare systems may alter investment decisions and should be taken into account. One field good at that is sociology, therefore, sociological concepts adopted in this framework are explained next.

1.2.2 Sociological perspective: Values, norms, states

In sociology, family relations are studied taking various socioeconomic factors into account which have often been neglected by evolutionary biologists. Investigations on caregiving, for instance, consider personal values and cultural norms or state-provided childcare. Wide spread sociological concepts are the **intergenerational solidarity** model (Roberts, Richards, &

Bengtson, 1991), the **intergenerational ambivalence** model (Lüscher & Pillemer, 1998), the synthesis of these two, the **intergenerational solidarity-conflict** model (Bengtson, Giarrusso, Mabry, & Silverstein, 2002), and the **hypothesis of intergenerational stake** model (Giarrusso, Stallings, & Bengtson, 1995). These models exist without an overarching framework but they all provide comprehensive approaches within which the complexity of family relations can be explored at several levels: (1) macro level (e.g., economic and cultural structures), (2) meso level (e.g., family constellations, emotions between generations), and (3) micro level (e.g., personal values, social roles, filial expectations). On the one hand, taking these levels and their changes over decades into account (proximate mechanisms) is critical when investigating contemporary human caregiving. Evolutionary biologists would be well advised to incorporate this approach. On the other hand, family sociologists study intergenerational relationships "without asking why particular emotions and norms exist or how they develop" (Danielsbacka, 2016, p.23). That is why the models mentioned above do not make clear predictions of causal determinants of human behaviour. Nevertheless, there are sociological concepts which do make empirically testable predictions. Four of these concepts, relevant to this framework, are presented next.

The **kin keeper** theory proposes that women are more involved in social bonding, due to cultural norms. Grandmothers, especially maternal ones, are therefore expected to provide higher levels of care to grandchildren than (paternal) grandfathers (Bracke, Christiaens, & Wauterickx, 2008; Dubas, 2001; Uhlenberg & Hammill, 1998). This theory therefore acknowledges differences in gender and lineage, yet, it is indifferent to biological relatedness. Even though sociological and evolutionary theorising varies markedly, they both lead to the same predictions in grandparental investment, stating that maternal grandparents invest more than paternal ones and women invest more than men (Danielsbacka, 2016).

The **gate keeper** theory emphasises emotions across generations, particularly between grandparents and their adult children (Robertson, 1975; Thompson & Walker, 1987). The latter are expected to have a critical mediating role in the grandparent-grandchild relationship. The emotional quality between grandparents, especially considering conflicts, and their adult children may determine whether or not and to what extent grandparents connect to their grandchildren. In contrast, evolutionary approaches typically assume that the provision of care is accepted without conditions. Moreover, the need for kin helpers in childrearing is strongly influenced by country-specific family policies, which evolutionary approaches usually do not take into account.

One of the most acknowledged approaches in sociology is the **life course perspective**. It is especially valuable when examining late life outcomes as it explores age-related trajectories across the lifespan (Bengtston, Burgess, & Parrott, 1997). Within the life course perspective, the cumulative **advantage/disadvantage perspective** (Graham, 2002; O'Rand, 1996) proposes that people who start out their lives with fewer resources will accumulate further disadvantages and fall further behind as they age. This perspective focuses on the impact of key life events such as marriage, (grand)parenthood, retirement or widowhood, suggesting that advantages and disadvantages are accumulated across the lifespan. Investigating grandparental investment in particular, this approach provides a valuable scientific basis to examine how the transition into grandparenthood affects grandparents' lives (e.g., health).

To conclude, sociological theories provide approaches within complex intergenerational relations that can be explored proximately, taking macro-, meso-, and micro level factors into account. Although some theories, such as the kin or gate keeper theory, do lead to the same predictions as evolutionary approaches, the main problem related to many sociological models is that they describe human behaviour rather than explaining it and lack an encompassing framework. Nevertheless, evolutionary (ultimate) and sociological (proximate) approaches do complement each other very well.

Next, the psychological perspective is presented with an integrative focus on both evolutionary and sociological approaches.

1.2.3 Psychological perspective: Individual goals and health across the lifespan

Similar to sociology, psychology does not ask why prosocial behaviour, and grandparenting in particular, exists at an ultimate level in humans (except for evolutionary psychology applying evolutionary reasoning as described above). Also in the so-called nature/nurture debate (Ridley, 2003), the question was discussed whether certain abilities are driven by our genes or by learning and environment. After decades of debating and advanced approaches (e.g., neurosciences) the result of this debate is that it is both nature *and* nurture intertwined. Why these abilities exist in humans at all was not specifically addressed. Cosmides and Tooby (1994) mentioned that the reason for this might be that parental caregiving, for example, is so prevalent and obvious that its existence does not seem to require an explanation.

Psychological research examines, for instance, the relation between social behaviour and factors like early life experiences (e.g., Verny, 1995), personality traits and psychopathology (e.g., van der Wat, Coall, Sng, & Janca, 2016), cognitive functions (e.g., Arpino & Bordone, 2014), and age-related trajectories such as successful aging (e.g., Gerstorf, Ram, Mayraz, Hidajat, Lindenberger, Wagner, & Schupp, 2010; Ouwehand, de Ridder, & Bensing, 2007). Most of these approaches do take variation across the lifespan into account, which is consistent with the sociological life course and cumulative advantage/disadvantage perspective. Yet, studies are scattered in the psychological fields ranging from social, personality, clinical, motivational, and developmental psychology to the neurosciences. Despite overlapping at some points, they lack an overarching framework. Nevertheless, they have developed comprehensive theories about social behaviour and their underlying processes such as **learning** (for a review, see Bednoz & Schuster, 2002) and **attachment** (Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1969, 1973). Although these processes are fundamental to human social behaviour, exploring them here would go far beyond the scope of this framework. The focus in this dissertation is more on prosocial behaviour and health at old age. Therefore, two developmental psychology approaches exploring the relation between caregiving and health are presented next.

The first is the **selection optimization, and compensation (SOC)** model which has proven to be one of the leading frameworks investigating processes involved in healthy aging (Baltes & Baltes, 1990). The model involves three processes: (1) selection of goals, (2) optimisation of functions and skills to reach goals, and (3) compensation for losses (for more details, see Freund & Baltes, 1998; Baltes, Lindenberger, & Staudinger, 2006). The SOC model provides a suitable framework to explore, for example, how people change and reach their goals under increased limitation in social, psychological or biological resources. The second psychological approach, the **socioemotional selectivity theory (SST)**, relates to the SOC model. The SST predicts that while people are younger, they aim at accumulating skills and knowledge, but when becoming older, shift their goals to maintaining social bonds and emotional closeness (Carstensen, 1995). Social interactions (e.g., helping others) may serve as remedies to reach these goals and prevent or compensate losses. In older adults, it has been shown that the shift towards maintenance goals is positively correlated with wellbeing (Ebner et al., 2006). Since subjective wellbeing is associated with physical health (Smith, Borchelt, Maier, & Jopp, 2002; Steptoe, Deaton, & Stone, 2015) orientation to and engagement in prosocial behaviour may contribute to healthy aging and longevity at a proximate level. Moreover, studies have shown that next to reaching spiritual peace and relieving burden or pain, strengthening relationships with loved ones was key to maintain the quality of life in terminally ill patients (Wilson, Graham, Viola, Chater, de Faye, Weaver, & Lachman, 2004; van der Maas, van Delden, Pijnenborg, & Looman, 1991). Impending death seems to highlight the importance of emotional and social goals regardless of age. Since normal physiological aging and increased limitations in functioning indicate approaching death, prosocial behaviour may be further enhanced in older adults (for related views on humans dealing with approximating death, see terror management theory (TMT), Greenberg, Solomon, & Pyszczynsky, 1992).

Overall, psychological research provides knowledge about fundamental processes underlying human social behaviour (e.g., learning and attachment). Theoretical frameworks, such as the socioemotional selectivity theory, do not examine human behaviour at an ultimate level, but they provide refining explanations as to why individuals do or do not engage in prosocial behaviour, why the importance of social interactions changes across the lifespan and how prosocial behaviour proximately contributes to healthy aging.

Having described the theoretical background, the coming section presents the aims and an overview of the empirical work completed in this framework.

1.3 Aims and structure of this framework

Five main aims are addressed: (1) to support the interdisciplinary effort in studying human caregiving by conceptually clarifying and bridging evolutionary, sociological, and psychological approaches. (2) To test the relevance of biological relatedness and other predictors of grandparental caregiving in the context of several contemporary European countries. (3) Assuming that biological relatedness still matters today, the third aim is to find answers as to why that may be. Thus, ultimate roots of human cooperation and hypothesised longevity and health benefits of mutual caregiving within and beyond kin are theoretically explored. (4) Based on these ultimate roots, the fourth aim is to empirically test whether longevity benefits are measurable in older European caregivers and if yes, whether health contributes proximately to the association between helping and longevity. (5) Lastly, to shed light on potential advantages regarding demographic change, specifically exploring a possible new niche for grandfather involvement in contemporary societies.

This framework is structured with a brief introduction, and then the empirical work presented is grouped into three sections.

In the first section (including manuscript 1), the question is examined, whether biological relatedness in contemporary European grandparental investment is still relevant. In addition, alternative factors (i.e., personal values, socioeconomic structures) are taken into account exploring the extent to which biological and non-biological grandparents provide care to their grandchildren. Potential explanations for why grandparents provide childcare to non-biological grandchildren are discussed.

In the second empirical section (including manuscript 2 and 3), the evolutionary roots of mutual caregiving are explored. A main topic discussed is how care within the family may extended to a hypothesised generalised caregiving system promoting prosocial behaviour towards non-kin (ultimate level). Furthermore, potential longevity benefits for the care providers are investigated. Moreover, it is examined how helping behaviour, health, and longevity are related on a proximate level.

In the third empirical section (including manuscript 4), the understudied issue of grandfather involvement in childcare in industrialised societies is addressed. It is discussed how demographic change may hold valuable opportunities for contemporary families, particularly for grandfathers.

In the discussion, a brief summary of the empirical findings is given and the strengths and limitations of this framework are examined. Finally, implications for future research and some personal conclusions are presented.

2. Empirical part

In the empirical part the research articles and book chapter are summarised, exploring human caregiving within and beyond the family, benefits for older caregivers and a potentially new niche for contemporary grandfathers.

2.1 Grandparental care within and beyond biological relatedness

There is considerable evidence that biological relatedness within a family matters. For instance, closer biological relationships (and closer attachment) between children and caregivers are associated with increased investment behaviours (Anderson, 2005; Daly & Wilson, 1980; Geary, 2000) and perceived obligations to those kin (Rossi & Rossi, 1990). Using the Survey of Health, Ageing and Retirement in Europe (SHARE), Danielsbacka, Tanskanen, Jokela, and Rotkirch (2011) showed that contemporary grandparents prefer to provide care for kin who are more likely to be genetically related (see kin selection theory in section 1.2.1). The authors showed that maternal and paternal grandmothers provided equal amounts of childcare only when the latter did not have grandchildren via a daughter who would have posed an investment opportunity in kin more certainly biologically related to them. Moreover, women and men who had grandchildren via both daughters and sons, looked after their daughter's children more often. In a study of contemporary Finnish aunts and uncles who had nieces and nephews via both their sisters and brothers, they had more contacts with their sisters' children (more certain kin) than their brothers' children (Tanskanen & Danielsbacka, 2015). Since emotional closeness and genetic relatedness both impact grandparental caregiving, Danielsbacka, Tanskanen, and

Rotkirch (2015) investigated both factors simultaneously. The authors found that maternal grandmothers provided greater amounts of childcare than paternal ones. However, emotional closeness to their daughters accounted largely for this difference. When emotional closeness was controlled, differences in the amount of childcare disappeared for maternal grandmothers, but were raised for paternal grandmothers. Thus, emotional closeness shaped the readiness to provide grandchild care differently for maternal and paternal grandparents. All these findings resonate well across disciplines, specifically with the assumptions of kin selection theory, biased grandparental investment, and the kin keeper theory (see sections 1.2.1 and 1.2.2).

At the same time, other factors are known to impact the level of investment by both biological and non-biological grandparents. For example, an individual's values, personal role expectation, or more practically, how far away the grandchild lives, play a role in grandparental investment decisions (see sociological models in section 1.2.2). Moreover, familial conflicts (Giarrusso, Feng, & Bentgson, 2005) can prevent grandparents from providing childcare to their grandchildren. Especially paternal grandparents often become alienated from their grandchildren after their son's divorce. For these grandparents, having the opportunity to invest in non-biological grandchildren may be the only way to live up to the grandparent role they were expecting. Simultaneously, a non-biological grandparent whose child has divorced and re-partnered may be older or less healthy, have other children and grandchildren to care for, feel less obligated to the new family, or live further away. Such factors would affect the availability of resources for a non-biological grandparent.

Next to these individual characteristics at the micro and meso-level, it is also important to consider macroeconomic factors potentially impacting grandparental investment, such as the interaction between welfare-state systems and grandparental investment. Using SHARE, Hank and Buber (2009) found a north-south gradient with regard to grandparenting in Europe. Their findings suggest that the higher availability of state-provided childcare in northern European countries promotes maternal employment, meaning that grandparents are commonly needed on a non-intensive basis to supplement institutional care. Conversely, in Mediterranean countries, where state-run childcare is less widespread and more expensive, levels of maternal employment are lower and grandparental investment less common, but more intense when it occurs. Sear and Coall (2011) investigated the implications of this association further and found that low levels of intense care and high levels of any care were strongly associated with higher fertility rates across Europe. Thus, regional differences in state-provided childcare and female employment rates, which may be reflected in national fertility rates, also have consequences for the grandparental investment in contemporary industrialised nations.

There are manifold ways grandparental caregiving can be impacted. Perhaps the most controversial and divisive issue between disciplines is the role of biological relatedness (Rose, 2001). Questions other disciplines would ask of the evolutionary perspective are time based. For instance, is the biological relationship between family members still relevant in contemporary societies? Have contemporary humans not overcome this Stone-Age like behaviour of caring only for kin? Are there not myriads of other – non-biological – factors driving mutual care between human individuals? These questions were addressed in manuscript 1. In the following, a brief overview of manuscript 1 is presented. The complete article including tables, figures, supporting information, and the author's comment can be found in appendix A.

2.1.1 Manuscript 1

Coall DA, Hilbrand S, Hertwig R (2014). Predictors of Grandparental Investment Decisions in Contemporary Europe: Biological Relatedness and Beyond. PLoS ONE 9(1), e84082. doi:10.1371/journal.pone.0084082

Research questions

The first research question examined whether biological and non-biological grandparents varied in their levels of grandparental investment and other socioeconomic characteristics at the micro-level (participants), meso-level (participant's children and their grandchildren), and macro-level (region and fertility rates).

Assuming that non-biological and biological grandparents differ systematically on socioeconomic factors, the second research question investigated whether these socioeconomic characteristics were associated with both biological relatedness and grandparental investment.

The third research question tested whether the variation among biological and non-biological grandparents fully accounted for differing investment levels – or if biological relatedness was an indispensable explanatory factor for grandparental investment in contemporary Europe.

Methods

In order to study these questions, first wave data (2004) from the large and multinational Survey of Health, Ageing and Retirement in Europe (SHARE) were used. Data were collected across 12 countries from a representative sample of participants aged 50 or older and their partners. A computer-assisted interview and paper-and-pencil questionnaire covered aging-related topics such as health, social and family networks, and financial situation (for details, see Börsch-Supan

& Jürges, 2005). In manuscript 1, the sample was restricted to respondents (generation 1: grandparents; G1) from northern, central, and southern Europe who had either biological or non-biological children (generation 2: children; G2) and at least one grandchild (generation 3: grandchildren; G3). This procedure resulted in 22,967 dyadic observations of which 20,710 were categorised as biological and 2,257 as non-biological. It is important to note that grandparents' (G1) investment in grandchildren (G3) was explored through the grandparent – adult child dyad (G1–G2). As such, most of the variables explored, including biological relatedness, reflected the grandparent–adult child relationship (see gate keeper theory in section 1.2.2). Information on the sex of grandchildren (G3) and their biological relationship to their parents (G2) were not available in the SHARE dataset. A detailed overview of the descriptive data is available as supporting information (SI, see appendix A).

Grandparental investment was operationalised as how often participants, independently of their spouse, had looked after their grandchildren (G3) without the presence of the parents (G2) in the last twelve months. Responses ranged from almost daily (5), almost weekly (4), almost monthly (3), and less often (2) to never (1). Investigated demographic variables were *age, health, sex, lineage, distance to grandchild, family size, employment, relationship status, family obligations* and *conflict, geographic regions*, and *fertility rates*.

Statistical procedures included inferential significance tests of mean and median differences as well as correlations to examine differences and relations among investment levels, biological relatedness, and socioeconomic factors (research questions 1 and 2). All variables being associated with both biological relatedness and investment levels (results from research question 2) were entered into a multinomial logistic regression model predicting odds ratios of grandparental investment levels for both biological and non-biological grandparents, relative to non-investing grandparents (research question 3). In addition, predicted probabilities of grandparental investments were saved (including the influence of the covariates) and their mean differences between biological and non-biological grandparents were examined via multivariate analysis of variance.

Results

The first point examined was whether biological and non-biological grandparents differed in levels of grandparental investment as well as in various socioeconomic factors (research question 1). Results showed that the proportion of biological grandparents reporting investment on a daily basis was more than double that of non-biological grandparents (8.8% versus 3.8%). Likewise, significantly more biological than non-biological grandparents looked after their grandchildren on a weekly basis (15.5% versus 11.4%). However, more non-biological than biological grandparents reported investing time on a monthly basis or less often, and around 50% of both groups reported no investment at all. Furthermore, the majority of socioeconomic characteristics differed significantly between biological and non-biological grandparents. Some of these differences were likely to favour higher investments by biological than non-biological grandparents (e.g., sense of obligation, smaller distances), whereas others impeded investments (e.g., older age, poorer health).

Secondly, it was examined whether socioeconomic characteristics of grandparents, their children and grandchildren, European regions and fertility rates were associated with both biological relatedness and grandparental investment (research question 2). Results suggested that variation in investment levels between biological and non-biological grandparents could be due to variation in biological relatedness, socioeconomic factors, or a combination of both. For example, biological grandparents were more likely to be grandmothers, felt more obliged to help their family, and lived closer to their grandchildren than non-biological grandparents. These factors are likely to enhance investment levels of biological grandparents. On the other hand, there were characteristics likely to decrease investments made by biological grandparents. They were older, reported poorer health and more conflicts with their children (G2) than non-biological grandparents.

Thirdly, it was investigated whether or not biological relatedness was an indispensable explanatory factor in explaining different investment patterns by grandparents in contemporary Europe (research question 3). Results from multinomial logistic regression analyses showed that biological grandparents were 1.5 times more likely than non-biological grandparents to invest on a daily ($p < .04$) or weekly basis ($p < .02$), relative to non-investors. There was no significant difference between these two groups at the level of monthly or less frequent investment. Many of the covariates were also predictive for investment levels. For example, positive associations were found between stronger feelings of obligation or younger age across all generations and higher investment levels. Better grandparental health was significantly associated with both high and low investments. It could be speculated that healthy grandparents do have the capacity to provide childcare but at the same time, also to do other things, such as meeting friends or travel, instead of providing childcare. The variables fertility rates and European regions both indicated more frequent grandparental investment in the southern countries, where fertility rates are also lower than in the north. These results are in line with Hank and Buber (2009), who found that grandparental investment is prevalent across Europe, but more intense in the southern countries.

Additionally, the mean differences between biological and non-biological grandparents in the estimated probabilities of grandparental investment levels were examined (multivariate analysis of variance). The most striking result was that biological grandparents were significantly more likely than non-biological grandparents to invest at both extremes of the investment spectrum (Wilks' lambda = .90, $F(4, 3813) = 106.69$, $p < .0005$, partial $\eta^2 = .10$), meaning that biological grandparents were more likely to invest heavily or nothing at all. In manuscript 1, this finding is referred to as the grandparental paradox.

The robustness of these results was tested by conducting a linear mixed effects analysis which used both fixed and random effects that correspond to the hierarchy of clustering in nested data (Seltman, 2012) within families and regions. This re-analysis confirmed the results of the main analyses (see the author's comment in appendix A).

Summary and implications

The finding that the biological relationship between grandparents and grandchildren is an independent predictor of high grandparental investment, even in contemporary European nations, is consistent with kin selection theory (Hamilton, 1964). Equally important, it was shown that socioeconomic factors, often neglected by evolutionary biologists, affected these decisions at a proximate level. Specifically, results indicated a curvilinear association between biological relatedness and investment levels (grandparental paradox). This finding showed that biological grandparents were most likely to invest either at high levels or nothing at all, while non-biological grandparents were most likely to invest at medium levels. Central to understanding this paradox is the fact that biological and non-biological grandparents systematically differ in various socioeconomic characteristics that affect investment levels (e.g., female sex, closer proximity to grandchildren, stronger feelings of duty to their family). At the same time, biological grandparents were also more likely to be older, in poorer health, and they had more conflicts with their adult children (G2) than non-biological grandparents. This study clearly highlighted the complementary nature of ultimate and proximate explanations when trying to understand variation in grandparental investment.

What these findings do not show, whatsoever, is whether these investments made by biological and non-biological grandparents are beneficial to grandchildren or grandparents. Nevertheless, there is mounting evidence suggesting that grandparental care improves contemporary grandchildren's wellbeing (Ruiz & Silverstein, 2007), emotional skills (Tanskanen & Danielsbacka, 2012), and educational achievements (Pallock & Lamborn, 2006), especially in low resource environments (Taylor, Marquis, Batten, & Coall, 2016). Less is known about potential benefits for grandparents, for example, in terms of longevity. This issue is addressed in section 2.2. Moreover, since manuscript 1 showed that biological relatedness still influences grandparental care today, the question as to why this may be is theoretically explored. In addition, it is reviewed how helping behaviour may have evolved within the family and went beyond.

2.2 Ancient benefits for caregivers today

Not only in ancient times (Hrdy, 2009), but also in contemporary traditional societies with high fertility and high child mortality rates (Sear & Mace, 2008), it is still crucial for grandchildren's survival to have helping grandparents around as long as possible. According to the grandmother hypothesis, menopausal women who helped to raise their grandchildren enhanced their own inclusive fitness by improving the reproductive success of their children (Hawkes et al., 1997; Hawkes et al., 1998; Sear & Coall, 2011). Enhanced inclusive fitness through helping behaviour thus constituted one beneficial consequence for grandparents. Moreover, the longer grandparents were alive and healthy enough to support their children with child rearing, the higher the chance their grandchildren would survive until breeding age. Grandparenting, especially grandmothering, is thus seen as conferring a selective advantage that has driven human longevity on an ultimate level (Hawkes & Coxworth, 2013; Kim et al., 2014). This ultimate mechanism is hypothesised to have extended beyond the limits of the family. The logic of this assumption is described next.

Based on the neural circuitry involved in parenting (see Numan, 2006) it has been proposed that a generalised neural and hormonal caregiving system developed through human evolution (Brown et al., 2011). Prosocial behaviour may have extended from parenting and grandparenting beyond the family through this caregiving system (also see Chisholm, Coall, & Atkinson, 2016). Specifically, seeing another person in pain or need (see de Waal, 2008) may activate the neural caregiving circuitry, thus enabling prosocial behaviour (Brown & Okun, 2014). This caregiving system is thought to be the ultimate foundation of caregiving towards non-kin that – on a proximate level – operates through compassion and empathy. This would also be in line with the suggestion that empathy may have both a phylogenetic and ontogenetic basis in the emotional bond between parent and offspring (de Waal, 2008; Preston & de Waal, 2002) but, when activated, can be extended beyond the family (Hrdy, 2009). These emotional pathways link helping behaviour to regulatory physiological systems (Porges, 2001, 2003; Porges & Carter, 2011), which could be among the proximate mechanisms impacting health and longevity. Moreover, these emotional pathways maybe key to the question why empathy and compassion is uniquely well developed in humans, compared to other cooperative breeders. One argument is that infants activate the caregiving system of their caregivers by actively evoking empathy and compassion (Hrdy, 2009). Right after birth, newborns can, for example, babble, gaze at their mother's eyes, or imitate facial expressions. These innate abilities to communicate with caregivers may be a strategy of the newborn to ensure being cared for, independent of genetic relatedness. At an ultimate level, prosocial behaviour towards non-family members may thus recruit the same neural circuitry as parenting and grandparenting does (Brown et al., 2011).

To reiterate, we all carry the genes for cooperation from our evolutionary past, which are likely to be associated with longevity. Drawing on this determination, there are several questions to ask. For instance, to what extent may the act of caregiving contribute proximately to our survival today? Do caregivers live longer than non-caregivers? What other factors may play a role in whether or not care influences longevity? More specifically, regarding the contemporary context currently placed on grandparents, other questions arise. For example, does the longevity of grandparents who provide care for their grandchildren differ from those who do not? Moreover, does helping behaviour towards non-kin also promote survival, and – if so, to what extent? This last question is particularly important considering the growing number of childless older adults in industrialised societies. In manuscript 2, briefly summarised below, these questions were examined. The complete article including tables, figures, and supporting information can be found in appendix B. Note that the term mortality rather than longevity is used throughout the summary of manuscript 2 in order to enhance reader's convenience, particularly in the result section.

2.2.1 Manuscript 2

Hilbrand S, Coall DA, Gerstorf D, Hertwig R (2016). Caregiving Within and Beyond the Family Is Associated with Lower Mortality for the Caregiver: A Prospective Study. Evolution and Human Behavior, advance online publication.
doi:10.1016/j.evolhumbehav.2016.11.010

Research questions

The first research question examined whether caregiving grandparents had lower mortality than non-caregiving grandparents and non-grandparents.

Older adults who cannot provide grandparental care because they have no grandchildren were examined next. Parents without grandchildren can nevertheless support their adult children.

Therefore, the second research question investigated whether those parents who helped their adult children had lower mortality than those who did not.

The third research question explored whether childless participants who provided help within their social network, beyond the nuclear family, had lower mortality than non-helpers.

Methods

To examine these research questions, data were drawn from the longitudinal Berlin Aging Study, BASE (Lindenberger, Smith, Mayer, & Baltes, 2010; see also https://www.base-berlin.mpg.de/en). BASE is a multidisciplinary investigation of the physical, cognitive and social characteristics of people aged 70 or older living in the former West-Berlin (mean age = 85 years, N = 516). The BASE sample was randomly selected from the West-Berlin registration office records. Those who agreed to participate completed interviews and medical tests at their homes, doctors' practices and hospitals. The assessments were repeated at approximately 2-year intervals between 1990 (interview time 1 [T1]) and 2009 (interview time 8 [T8]). The BASE dataset contains extensive information on a range of health and social conditions obtained from the participants (generation 1, G1) as well as information provided by G1 about all of their children (generation 2, G2) and grandchildren (generation 3, G3). Updates on mortality status were obtained regularly from the municipal authority until 2009. A detailed overview of the descriptive data is available in appendix B.

Mortality was defined as how many years participants lived following the interview at T1 and is thus a prospective variable. *Caregiving* was measured as the frequency of grandparental caregiving without the parents being present in the twelve months prior to T1. This variable ranged from 1 (never) to 7 (every day). Note that there were no cases of grandparental caregiving on a daily basis, in other words, the sample did not include any primary or custodial caregivers. Participants were categorised as *caregiving grandparents* (n = 80), *non-caregiving grandparents* (n = 232), *non-grandparents* (n = 204), *helping parents* without grandchildren (n = 167), *non-helping parents* without grandchildren (n = 203), and *childless participants* who provided help within their social network (n = 101) or not (n = 52). The support of helping parents was measured in terms of *instrumental help* provided to their adult children (e.g., aid with housework or fixing things) in the twelve months prior to T1 (yes versus no). The support of childless participants was measured in terms of *emotional and instrumental support* provided beyond the nuclear family (e.g., comforting others, aid with housework or fixing things) in the three months prior to T1 (yes versus no). A large set of covariates across the three generations were controlled for in all analyses: *Health, sex, age, education level, family size, relationship status, income, support received, proximity to grandchildren*, and *biological relatedness*.

Statistical procedures included survival analyses (Cox regressions), which determined the probability (hazard ratio, HR) that an event (death) will occur within a specified time interval in a given group (e.g., caregiving grandparents) relative to the reference group (e.g., non-grandparents). These analyses accounted for the so-called censored data. That is, adjusting for missing information on mortality (10.3% of the individuals that were either still alive or lost to follow up). To test the robustness of results, missing information was also estimated using the multiple imputation procedure (IBM, 2011) and linear regression analyses were conducted with complete data sets. These analyses yielded very similar results to the survival analyses and were thus considered to be robust. Results of the linear regression analyses are available in the supporting information (see appendix B).

Results

The first research question examined whether caregiving grandparents had lower mortality than non-caregiving grandparents and non-grandparents. With a hazard ratio (adjusted for covariates) of .63, results indicated that the mortality hazard among caregiving grandparents was 37% lower relative to non-caregiving grandparents and non-grandparents ($p < .05$). The mortality of non-caregiving and non-grandparents did not differ significantly. Covariates contributing significantly to survival were better functional health, female sex, and younger age of the participants.

Parents (G1) who did not have grandchildren were examined next. The second research question asked whether helping parents had lower mortality than non-helping parents. With a hazard ratio (adjusted for covariates) of .43, results indicated that the mortality hazard among helping parents was 57% lower relative to non-helping parents ($p < .001$). Covariates significantly associated with survival were the participants' lower comorbidity, female sex, and younger age of the participant.

The third research question asked whether childless participants, who provided help within their social network beyond the nuclear family, had lower mortality than non-helpers. With a hazard ratio (adjusted for covariates) of .40, results showed that the mortality hazard was 60% lower among helpers, relative to non-helpers ($p < .001$). Covariates significantly associated with survival were better functional health, female sex, and younger age of the participants.

Summary and implications

The finding that helping behaviour within and beyond the family was consistently associated with lower mortality for the helper (after adjusting for prior health, age, support received, various socioeconomic characteristics, and biological relatedness) indicates that caring for others indeed does contribute proximately to survival today. This finding also adds evidence to the hypothesis that there is an ultimate foundation linking prosocial behaviour with survival. Additionally, taking advantage of the rich set of covariates available in BASE, including prior health and socioeconomic characteristics across all three generations, allowed the ruling out of competing explanations for the survival advantage conferred by caregiving (e.g., see cumulative advantage/disadvantage perspective in section 1.2.2). These findings, however, should not be interpreted as a panacea for a long life. Whether or not caregiving is beneficial for the caregiver may strongly depend on the level of caregiving (see Coall & Hertwig, 2010; Glaser et al., 2014). As mentioned before, there were no primary caregivers in the BASE sample and that may contribute to the strong association between caregiving and mortality here.

Based on findings from manuscript 1 (grandparental paradox), it could be assumed that biological grandparents who are more likely to provide either high levels of childcare or none (both impeding grandparental health, see Coall and Hertwig, 2010) would have higher mortality. Moreover non-biological grandparents who are more likely to provide medium levels of childcare (associated with health benefits, see Glaser et al., 2014) could be assumed to have lower mortality. However, biological relatedness was not among the covariates found to significantly impact mortality. This indifference may be due to two reasons: (1) in BASE there were no cases of intense grandparental caregiving and (2) the number of non-biological grandparents was very small (n = 26) hindering the detection of such differences.

Although the relationship between helping behaviour and mortality was confirmed, these results did not predicate anything about (1) the quality (e.g., health) of a prolonged life or (2) the potential causal proximate mechanisms underlying this association. This issue is addressed below.

There is growing evidence that medium levels of grandparental caregiving are associated with health benefits for grandparents (Glaser et al., 2014). For example, the provision of childcare has been shown to have a positive effect on grandparents' cognitive functioning (Arpino & Bordone, 2014) and subjective wellbeing (Mahne & Huxhold, 2015). Furthermore, grandparental care reduced the grandparents' risk of depression (Grundy, Albala, Allen, Dangour, Elbourne, & Uauy, 2012). Research on helping behaviour beyond the family also indicates that voluntarily supporting others has beneficial effects on a variety of supporter's health outcomes (e.g., Brown, Brown, House, & Smith, 2008; Kahana, Bhatta, Lovegreen, Kahana, & Midlarsky, 2013; Morrow-Howell, Hinterlong, Rozario, & Tang, 2003; Musick, Herzog, & House, 1999, Tanskanen & Danielsbacka, 2016) as long as the help provided does not overtax the helpers physically or psychologically (Post, 2005). Moreover, helping behaviour towards friends, neighbours, or relatives have been found to reduce mortality (Poulin, Brown, Dillard, & Smith, 2013). Similarly, in their meta analysis focusing on older adults, Okun, Yeung, and Brown (2013) found that volunteering was consistently associated with survival benefits of the volunteer. These findings are all in line with predictions from the socioemotional selectivity theory (SST, see section 1.2.3), stating that older individuals shift their goals to maintaining social bonds, which in turn contributes to healthy aging (Löckenhoff & Carstensen, 2004).

However, previous work has often focused on either the association between helping behaviour and health outcomes *or* the association between helping behaviour and survival benefits. Yet, little is known about whether or not, and if yes, to what extent, health benefits resulting from helping translate into survival benefits. Health may contribute strongly, but does it fully account for longevity benefits? According to SST, caring for others at an old age contributes to maintaining better subsequent health and through this proximate path to lower mortality.

The study in manuscript 3 tested this hypothesised path and is briefly summarised below. The complete article including tables, figures, and supporting information can be found in appendix C. Note that in manuscript 3 the term longevity rather than mortality is used in order to emphasise the assumed positive relationship between help, health, and survival benefits.

2.2.2 Manuscript 3

Hilbrand S, Coall DA, Gerstorf D, Meyer AH, Hertwig R (2016). A Prospective Study of the Relationship between Helping, Health, and Longevity. Submitted for publication.

Research questions

The first research question examined whether the relationship between non-intensive grandparental caregiving and enhanced longevity was mediated by better subsequent health.

The second research question explored whether the relationship between moderate levels of support provided beyond beyond the nuclear family and enhanced longevity was mediated by better subsequent health.

Methods

To investigate these research questions, data were again drawn from BASE and missing information was estimated using multiple imputation procedures (IBM, 2011). For details on the estimation process, see the supporting information in appendix C.

Longevity indicated how many years participants lived after T1 and is thus a prospective variable. As in manuscript 2, the variable measuring *grandparenting* did not include intense (daily) levels of childcare. The variable measuring *support given to others* in the social network indicated the sum of different kinds of support provided in the three months prior to T1. This included instrumental support (e.g., fixing things) and/or emotional support (e.g., comforting someone) and ranged from 0 (no support given) to 6 (maximum number of support given). In terms of health, Z-standardised *health indices* were computed reflecting physical and mental health at interview time 1 and 3 (T3, 5-6 years after T1). They consisted of four subscales: comorbidity (number of physician-observed diagnoses), functional health (Instrumental Activities of Daily Living, IADL), cognitive functioning (Mini Mental State Examination, MMSE), and depression (Hamilton scale, HAMD). Prior health status was controlled for by the Z-standardised health index at T1 (equivalent to T3). The same covariates investigated in manuscript 2 were taken into account in the analyses in manuscript 3 (except biological relatedness). A detailed overview of the descriptive data is available in appendix C.

Two mediation analyses (structural equation models adjusted for covariates) were conducted. In the first model, *grandparenting* was the independent variable, *health index at T3* was the mediator, and *longevity* the dependent variable. Only grandparents were included in this analysis ($n = 312$). In the second model, *supporting others* was the independent *variable, health index at T3* was the mediator, and *longevity* the dependent variable. Only childless participants were included in this analysis ($n = 153$) to ensure that the support did not go to children or grandchildren. Covariates in both models were socioeconomic characteristics of the grandparents, children, and grandchildren, and support received from others. Because grandparenting was correlated with supporting others in the social network, the latter was included as a covariate in model 1.

Results

Model 1 examined whether the relationship between grandparental caregiving and longevity was mediated by subsequent health. Results showed that higher levels of grandparenting were significantly associated with better subsequent health, which in turn was significantly associated with higher longevity ($B = .20$, $p < .001$). However, the relationship between grandparenting and longevity remained significantly positively associated ($B = .88$, $p < .001$). This meant that grandparenting, independent of subsequent health, contributed to longevity. Therefore the mediation was incomplete (subsequent health mediated 18.7% of the relationship between grandparenting and longevity). The model explained 86.5% of the total variance of longevity (adjusted R^2).

Model 2 examined whether the relationship between supporting others and longevity was mediated by subsequent health. Results again showed that higher levels of supporting others were significantly associated with better subsequent health, which in turn was significantly associated with increased longevity ($B = .51$, $p < .001$). At the same time, the relationship between supporting others and longevity remained significantly positively associated ($B = 1.26$, $p < .001$). This meant that supporting others, independent of subsequent health, contributed to longevity. Therefore the mediation was incomplete (subsequent health mediated 28.8% of the relationship between supporting others and longevity). The model explained 80.3% of the total variance of longevity (adjusted R^2).

Summary and implications

Grandparental caregiving, as well as supporting others beyond the nuclear family, were not only associated with longevity of the helper, but were partially mediated by better subsequent health. This finding complements previous work that focused on either health *or* longevity benefits, but not the paths between them. Furthermore, the finding is in line with predictions from SST, proposing that older adults focus on maintaining social bonds (e.g. through helping) which contributes to healthy aging (see section 1.2.3). This finding provides a first step towards identifying possible proximate mechanisms underlying the relationship between helping behaviour and longevity, complementing the evolutionary and sociological perspective with a psychological explanation. Since the mediation was incomplete, it is most likely that other (unobserved) factors contributed to the pathways between helping, health, and longevity. Potential candidates are discussed next.

First, the measurement of health in the analysis of manuscript 3 needs to be acknowledged. Although health indices did include indicators of physical and emotional health (i.e., depression) other indicators, like for stress, were not available in BASE. This being unfortunate because emotional regulatory systems involve pathways linked to human stress-responses; therefore, investigating stress-related hazards may further illuminate the link between helping behaviour, health and longevity. A recent study points to prosocial behaviour as an effective strategy in reducing the impact of stress in everyday life as it influences biological systems, including stress-regulating hormones such as oxytocin (Raposa, Laws, & Ansell, 2016). This argument is in line with findings from Poulin et al. (2013) who found helping behaviour to be a stress buffer which in turn enhanced survival. Both studies complement the evolutionary argument that the ultimate foundation of the human caregiving system evolved from (grand)parenting and proximately operates through emotions (e.g., compassion) and stress regulatory systems (e.g., oxytocin), thus influencing health and longevity.

Another candidate is the quality of the relationship between care provider and receiver. For example, maintaining a relationship with paternal grandparents, who are often alienated after a new step-family is formed, is beneficial to the behavioural adjustment and mental health of both grandparents and grandchildren (Attar-Schwartz, Tan, Buchanan, Flouri, & Giggs, 2009; Bates & Taylor, 2012). Social strain afflicting intergenerational relationships not only leads to a decline in health (Tun et al., 2013), but also decreases the probability of the helping behaviour within these relationships (Coall, Hilbrand, & Hertwig, 2014). Therefore, the emotional quality of a relationship (i.e., attachment) may moderate the effect between helping and longevity (Merz, Schuengel, & Schulze, 2007).

Also participants' motives for helping may play an important role in whether or not helping behaviour results in health and longevity benefits. These benefits have previously been found only when volunteering was other-oriented but not reciprocity-oriented (Konrath, Fuhrel-Forbis, Lou, & Brown, 2012). From an evolutionary perspective, it is plausible that other-orientation evolved within the family (see caregiving system in sections 1.2.1 and 2.2). It follows the assumption that helping behaviour is not primarily driven by reciprocity based motives (see Kurzban et al., 2015 for a review of human altruistic behaviour). In BASE, the motives for helping were not available, but the support received was controlled for in manuscript 3. Thus, the competing explanation that receiving reciprocal support, somehow mediates the relationship between helping and longevity (see rational grandparent model, Friedman, Hechter, & Kreager, 2008), could be ruled out. Yet, other factors may contribute to this relationship and the examination of multiple proximate pathways may reveal a more detailed picture of underlying causal mechanisms (Ebner et al., 2006; Lang, Rieckmann, & Baltes, 2002).

In manuscript 3, a first step was taken showing that caring for others may be among the top candidates contributing to healthy ageing and longevity. These findings raise the question whether promoting helping behaviour within and beyond the family would be a cost effective and sustainable means to stimulate healthy ageing and longevity covering large parts of society. In Western contemporary societies, however, social engagement has been attributed mainly to the women (see lineage and kin keeper theory in sections 1.2.1 and 1.2.2). How men socially engage and probably benefit, particularly from grandfathering, is yet to be understood. This issue is addressed in section 2.3 where an interdisciplinary perspective on grandfathering is presented. Below, the main points of the book chapter (manuscript 4) are briefly summarised. The entire chapter can be found in appendix D.

2.3 Grandfathers

In the grandparent-based literature, grandfathers have been largely overlooked. Scientific research has just started to show interest in investigating the roles grandfathers play in their families today. First evidence points that these roles are independent and different from that of grandmothers (Knudsen, 2012) and affect not only the health and wellbeing of grandfathers (e.g., Bates & Taylor, 2016), but also that of their grandchildren (e.g., Tanskanen & Danielsbacka, 2012).

2.3.1 Manuscript 4

Coall DA, Hilbrand S, Sear R, Hertwig R (2016). A New Niche? The Theory of Grandfather Involvement. In A Buchanan and A Rotkirch (eds), Grandfathers. Global Perspectives. London, UK: Palgrave Macmillan. doi:10.1057/978-1-137-56338-5

In the field of grandparental research – often dominated by Western researchers – grandfathers have been viewed as passive, remote and disengaged (Roberto, Allen, & Blieszner, 2001). With rapidly changing family structures and a concomitant change in the potential role of both grandmothers and grandfathers, research is slowly moving from a strong focus on grandmothers to also include the specific roles of grandfathers. Crucially, this new line of research moves away from the view of grandfathers being disengaged.

From an evolutionary perspective, there is yet little reason to assume that care from grandfathers provides an adaptive explanation as to why grandparents exist, in the same way that care from grandmothers may explain the evolution of post-reproductive women (see grandmother hypothesis in section 1.2.1). In fact, current evolutionary based evidence does not preclude that grandfathering has beneficial effects at the family or individual level. For example, Sear and Mace (2008) found evidence that the presence of grandfathers painted a different picture compared to grandmothers. In 83% (10 of 12 studies) of cases, the presence of maternal grandfathers was not associated with child survival (only in the remaining 2 studies it had a positive association). In the case of paternal grandfathers, 50% of studies showed no effect (6 of

12 studies), 25% had a positive effect and the remaining 25% showed that the presence of the paternal grandfather was associated with reduced child survival. When examining a historical Finnish population (1714-1839), Lahdenperä, Russell, and Lummaa (2007, 2011) found no evidence that that the grandfathers who lived longer ultimately had more surviving grandchildren. Nevertheless, contemporary grandfathers do make notable contributions to their grandchildren's care that come close to those made by grandmothers (Hank & Buber 2009). Is this a new adaptive niche?

From a sociological perspective, the ever-increasing investment in fewer children means that nuclear families require heavy investment from vertical kin (e.g., grandfathers) in the absence of support from broad, horizontal kin networks. Moreover, with the advent of social security systems, such as receiving pensions after retirement, grandfather availability has potentially opened new investment opportunities, including childcare. Therefore, as fathering has, grandfathering may now become a more important resource for the family, providing grandfathers with the opportunity to carve out their own new niche.

Consistent with this high-investment niche, the research literature shows that grandfathers, who are becoming actively involved, do make a difference in their grandchildren's lives. For example, Scholl-Perry (1996) investigated the influence of grandparental investment on academic achievement and found that the social distance to grandfathers, but not grandmothers, was associated with grade point average. The evidence that grandparents, including grandfathers, have a positive influence on grandchild development is growing. The niche seems to be particularly important in low-resource environments, such as single-parent families and families experiencing poverty (Radin, Oyserman, & Benn, 1991). In a study of sixty-six multigenerational, teen-mother families in Detroit (USA), with biological fathers absent and grandchildren between 1 and 2 years of age, higher levels of grandfather nurturance were associated with the children being more likely to comply with their mothers' requests (Oyserman, Radin, & Benn, 1993). Moreover, the authors found that higher levels of grandfather involvement substantially reduced negative affect in grandchildren. These effects remained robust after adjustment for socioeconomic status, father's age and hours of grandfather employment. Interestingly, there was no evidence of such grandmother effects in this sample.

However, grandfather research is still in its infancy. Future studies will have to piece together a more detailed picture how grandfather involvement affects contemporary families, including the grandfathers themselves.

Having illustrated the empirical part of this framework, the findings and further implications are discussed next.

3. Discussion

In the summary presented here, the five aims of this framework are reiterated and the empirical findings relating to each one are discussed.

3.1 Summary

The first aim of this framework was to support the interdisciplinary effort in studying human caregiving by conceptually clarifying and bridging evolutionary, sociological, and psychological approaches. Terms and concepts across disciplines have been described in the introduction and all four manuscripts incorporate interdisciplinary approaches showing that they complement rather than compete with each other. Differences among the disciplines' contributions are most salient in their structure of explanation.

The distinction between ultimate and proximate mechanisms, in particular, highlights the differences in the explanatory structures across these disciplines. Ultimate mechanisms are explored by evolutionary approaches (e.g., the evolution of cooperation) valuably being complemented by the proximate mechanisms investigated by the social sciences (e.g., micro-, macro-, meso levels). Thus these approaches are not at odds with each other, but rather only operate on different levels of explanation. Particularly regarding caregiving, sociological approaches making testable predictions such as the kin or gate keeper theory also lead to the same predictions as evolutionary approaches (e.g., lineage, sex-specific reproduction strategies) even the levels of exlpanation varies between the two disciplines. Also note that various approaches like the evolutionary life history, the sociological life course perspective, and the psychological SST, take variation (e.g., age, life stage, and environmental factors) into account that could influence human behaviour (e.g., caregiving). In addition, the psychological perspective offers refined explanations to inter- and intra-individual differences, based on fundamental psychological processes, such as learning or the shift of goals across the lifespan.

Overall, the empirical work presented in this framework shows, that an individual's ability to learn and adapt to changing environments does not invalidate the assumption that human behavioural traits may be universally rooted in our evolutionary past and that these roots still play a role in contemporary humans (also see Danielsbacka, 2016). Yet, individual and societal factors strongly influence whether or not and to what extent our evolutionary inheritance is expressed today.

The second aim was to test the relevance of genetic relatedness in grandparental caregiving in the context of various contemporary European countries. In manuscript 1, it has been shown that biological relatedness still influences contemporary grandparents' investment decisions (grandparental paradox). Moreover, a wide range of individual and structural socioeconomic factors, independent of biological relatedness, have impacted grandparents' investment decisions. Results from manuscript 1 showed that evolutionary and sociological constructs complement each other in explaining the variance in grandparental investment behaviour on an ultimate and proximate level. This finding highlights the need for an encompassing approach in this field.

The third aim was to explore the ultimate roots and hypothesised benefits of human cooperation and mutual caregiving within and beyond kin. An evolutionary based framework was presented in order to understand why cooperation and mutual caregiving exist at all and why they are so well developed in the human species. From an evolutionary perspective, it is legitimate to assume that the humans evolved as cooperative breeders relying heavily on allomothers (see section 1.2.1) and especially on grandmothers (Hrdy, 1999, 2009). This selective advantage is proposed to be the ultimate level that drives human longevity and the development of a neuronal and hormonal caregiving system enabling prosocial behaviour towards non-kin (Brown & Okun, 2014).

This caregiving system may proximately operate through empathy and compassion, independent of biological relatedness. Both are emotional states, which can be evoked by human infants enhancing their chance to be cared for and thus increase their likelihood of survival.

Overall, the presentation of this evolutionary framework showed that evolutionary theory provides a solid basis upon which sociological and psychological approaches can investigate the proximate mechanisms of human prosocial behaviour.

The fourth aim was to test whether or not the hypothesised longevity benefits are still traceable (manuscript 2) and if they proximately operate through health in the older caregivers in industrialised Europe (manuscript 3). The study in manuscript 2 showed that the act of both caregiving within and beyond the family is associated with longevity benefits for the caregivers, independent of prior health and various socioeconomic factors. Moreover, the study in manuscript 3 suggested that the relationship between helping behaviour and longevity is partially mediated by better subsequent health which is in line with predictions from the SST.

Yet, it remains an open question which other pathways may contribute proximately to health and longevity. As discussed before, there are multiple candidates such as stress-related hazards, quality of the relationship or motivational aspects (Post, 2005). In the study in manuscript 3, a first step was made to understand how helping, health, and longevity correlate; however, these pathways need further refinement.

The fifth aim was to shed light on potential advantages regarding demographic change; specifically, exploring a new niche for grandfather childcare involvement in contemporary societies. In manuscript 4, grandfather involvement was explored from different perspectives. From an evolutionary point of view, it was stated that there is yet very little known about why grandfathers do engage in childcare at an ultimate level, particularly in comparison to grandmothers. The role of grandfathers as allomothers has not been extensively investigated. It is also less clear if and to what extent grandfathers contribute to the wellbeing or educational achievements of their grandchildren. From a sociological point of view in regards to demographic change, grandfathering already is seen as a very important family resource. With the ongoing demographic changes, families can potentially rely more heavily on grandfather childcare in the future. Thus, the increased life expectancy may be especially valuable for grandfathers who can carve out their own new niche.

Next, the findings of this framework are evaluated in terms of strengths, significance, and limitations. Remaining open questions and guidelines for future research are addressed.

3.1.1 Strengths, limitations, open questions

In industrialised societies like in Europe, time is the one resource that most people involved in the labour market do not have. The prolonged period of shared lifespan across generations offers older adults the opportunity to spend precious time with their beloved ones. Investigating this fast growing segment in 21st century Europe is central to understand how older people contribute to society outside the working market. While in previous studies this aging segment of society often has been singled out as a burden, especially in terms of health care, here they are investigated as valuable contributors to society. In addition, caregiving is investigated at multiple levels, incorporating perspectives from evolutionary biology, sociology, and psychology. The significance in this interdisciplinary approach is that it provides answers as to why human caregiving exists at all, how it is shaped by socioeconomic and individual factors today, and how these ultimate and proximate mechanisms complement each other. Ultimately, the interdisciplinary perspective provides a fuller picture of human caregiving. Furthermore, exploring and incorporating ultimate mechanisms of caregiving offers an out-of-the-box perspective that can help discovering social and health potentials lying within these demographic changes. Moreover, in this framework, large scale representative data was used (manuscript 1 in particular) supporting a broader generalisation of the results more so than small non-representative data. Crucially, the longitudinal nature of the data (manuscript 2 and 3) allowed for the control of critical confounders, such as prior health or socioeconomic status, which is central to the cumulative advantage/disadvantage perspective (see section 1.2.2).

An obvious limitation of these datasets, however, is that they are all European data. The influence of specific cultural norms or welfare states could not be explored outside Europe. In manuscript 1, different European regions were taken into account, but for research questions posed in manuscripts 2 and 3 it would have been interesting to investigate the effects of helping behaviour on health and longevity across different cultures. This would have allowed for further elaboration of ultimate and proximate mechanisms and provided the opportunity to test universal evolutionary hypotheses in different parts of the world. Another limitation of the work presented in here is that Western researchers developed all approaches applied. A further interesting question would be, for instance, would other cultures with different views on family life lead to new ways of exploring human caregiving? For example, would research based on family models of the Bari people in Venezuela, who believe in partible paternity (that is, a child can have multiple fathers, see Beckerman, Lizarralde, Ballew, Schroeder, Fingelton, Garrison, & Smith, 1998), lead to different predictions on caring for kin, non-kin, and grandparental caregiving?

Another concern is the perspective of time during aging. Time and changes over time are conceptualised in relation to chronological age. However, studies have shown that perceived proximity to death alters individuals' goals (Wilson et al., 2004; van der Maas et al., 1991) and some health indicators are rather associated with the remaining time until death than with chronological age (Gerstorf et al., 2013). According to SST, older individuals tend to invest more heavily in social interactions, but this may be due to approaching death, rather than chronological age. Thus, caregiving could be investigated in relation to proximity of death, not in relation to chronological age. The same logic applies to the question how caregiving is influenced by time perception. Future research could look into the question whether investment decisions are influenced by the expected lifespan, chronological age, or a combination of both.

Lastly, another unanswered question is why did 50% of the grandparents (both biological and non-biological) in the SHARE sample report not to provide any care to their grandchildren? This issue has not specifically been investigated in manuscript 1, but as mentioned before, one could speculate, that healthier grandparents rather meet up with friends or go travelling than providing childcare. In addition, it could be that non-caregiving grandparents may be younger and still involved in the labour market, that they rather provide financial than personal support or that non-caregiving grandparents may have more conflicts with their adult children. In this framework this issue remains unclear. Having a more detailed picture would allow deriving social policy and health implications for the young, middle, and older generations to maintain strong social bonds within and beyond the family. This point is addressed next.

3.2 Implications

Understanding human caregiving is central to a broad range of fields (e.g., policy making, health care, psychological treatment). Thus, findings from this framework may aid in the knowledge about the development of mutual care, its relation to healthy aging, and how it can be promoted in the human species for public health benefits.

3.2.1 Relevance for social policy making

In regards to contemporary childrearing, the perspective of cooperative breeding provides strong arguments towards enhancing state-provided day care. This view emphasizes: (1) the importance of high-quality day care which permits caretakers to simulate an allomother environment (in particular, having enough staff in relation to the number of children), (2) the need for affordable high-quality day care in order to disburden working parents, (3) the benefit of such day care, since it would foster the development of the youngsters' social skills crucial for their wellbeing later in life (see cumulative advantage/disadvantage perspective in section 1.2.2), and (4) the opportunity for older adults to supplement the increased demands of such high-quality day care.

3.2.2 Relevance for health care

In this framework, older individuals are not only seen as beneficial to health care because they can buffer negative factors impacting grandchildren's wellbeing. But rather for their ability to enrich the younger generation by exposing them to mutual care that is crucial for the grandchildren's wellbeing, particularly in terms of how they form their intimate relationships once they have grown (Kaul & Fischer, 2016). Social interactions, in turn, are highly relevant for human wellbeing and health (Tun et al., 2013). Thus, involving grandparents and older adults in childcare is relevant to health care in two ways.

First, by helping others, the older caregivers can better maintain their health and reduce the likelihood of heavily depend on geriatric care. As analyses in manuscript 2 and 3 have shown, helping behaviour may also increase one's own life expectancy. There is an ongoing debate about how much the increase of life expectancy burdens health care systems (Breyer et al., 2010). One argument in this debate – called the red herring hypothesis (Zweifel, Felder, & Meier, 1999) – states that high health costs are not primarily due to ever increasing longevity, but are rather a function of time to death. That is, higher chronological age does not mean worse health and increased health care expenditure per se. Health costs are rather high with increasing proximity to death (end-of-life costs), thus more prevalent in the older segment of society. These costs may be postponed but remain inevitable as death does. Maintaining good health in late life means, economically speaking, not further accelerating health costs. From this point of view, helping others and thereby enhancing longevity is not accelerating health expenditure. It rather supports healthy aging and postpones inevitable end-of-life costs. The question is then not how long we are going to live, but rather how socially engaged and healthy we live our lives up until death's door.

Second, as mentioned before, grandparents and older individuals can step in as compassionate allomothers enabling the young generation to experience mutual care, which can foster the development of their social skills. Well developed social skills such as emotional self-regulation are central for wellbeing later in life (Kaul & Fischer, 2016). Therefore, involving older individuals in formal or informal childcare settings can be interpreted as a preventive measure in decreasing future health costs.

In addition to these two implications, other questions concerning members of the health care system are as listed. Considering that the provision of care evolved within the family, extended beyond the family and nowadays also is institutionalised, how does helping behaviour affect professional helpers (e.g., day care staff, nurses, psychotherapists)? Do the effects extend to professional helper's health and longevity? If yes, under which conditions would that be the case? These questions have not been addressed here, but certainly merit scientific attention. Applying interdisciplinary perspectives presented in this framework may provide additional arguments in the discussion about maintaining professional helper's health.

When transferring the above mentioned implications to social policies or to health care projects precaution is advised. These implications are all based on a critical presumption, often implicitly assumed in evolutionary biology or sociology research. Grandparents and older individuals are assumed to have the capacity for empathy and compassion well developed and naturally being able to provide mutual care to others. From a psychological perspective, this is not necessarily the case. Psychological approaches to this issue and practical tools are addressed next.

3.2.3 Practical approaches and tools from psychology

Learning is one of the main traits of human development. The brains of human newborns are surprisingly large compared to that of other mammals and develop at an impressively fast rate in the first few years (Allman, 2000). In the following section, the focus is set on social learning and on the development of **internal working models** in particular. Such models are defined as thinking processes, which are built on past experiences (for more details, see Bednorz & Schuster, 2002). The ability to mentally represent objects or processes has enabled us to invent practical things like baby bottles or smart phones. Considering social behaviour, mental representations serve as reference points, thus shaping the perception of a new situation as well as the reaction to that situation. They allow individuals to anticipate and predict what others may do and how to best respond or proactively act. These models are built at a very young age on the basis of internalised early social experiences made between a child and its main caregivers (Lyons-Ruth, Bronfman, & Atwood, 1999). Broadly speaking, early social experiences hardwire a child's brain which she or he will later use to formulate relationships (for a critical review, see Pietromonaco & Barret, 2000) and they are crucial for the development of empathy and compassion (for a review, see Preston & de Waal, 2002).

The internalisation of working models regarding human social interactions was emphasised by Bowlby and Ainsworth in the **attachment theory** (Ainsworth et al, 1978; Bowlby, 1969, 1973). Briefly summarised, it proposes that newborns and young children develop different styles of attachment to their primary caregiver – in Bowlby and Ainsworth's experiments typically the mother – depending on the attentiveness and responsiveness of the caregiver (for more details on attachment theory, see Bowlby, 2008). The style of attachment, so the argument goes, indicated how safe and cared for a child felt in relation to the caregiver. Taking the concept of cooperative breeding into account, this view would need to be broadened. Firstly, human newborns are able to feel safely attached to multiple caregivers; childrearing does not need to be mother-centred (Hames & Draper, 2004). Secondly, it is assumed that infants scan their environment (e.g., faces of caregivers) to gain information about how safe the environment is (Hrdy, 2009). Thus, the caregiver does not only serve as a basis for the attachment style, he or she is also used by the infant to learn about what kind of environment there is beyond the caregiver (i.e., are there enough resources or any threats?). Moreover, the building of these internal models and attachment styles is not a one-way street. At this point it is important to recognise the baby as a protagonist with innate abilities such as crying, vocalising or imitating facial expressions of the caregiver right after birth. These abilities are not unique to humans, but they are especially well developed in our species (Hrdy, 2009). One reason might be that they deepen the bond between newborns and their caregivers as they act and react to each other's signalling. Empathy and compassion involved in these processes may therefore have both a phylogenetic and ontogenetic basis (de Wall, 2008).

The building of internal working models and the development of empathy and compassion is a dynamic process, in which both the baby and the caregiver play an active role. It follows the assumption that grandparents and older adults who have not experienced mutual care when they were young, have a decreased capacity for empathy and compassion necessary for mutual care. Their internal working models, developed at a young age, probably adapted to the lack of mutual care. Most likely, this adaption would have been imperative for their mental or physical survival at a young age, but becomes dysfunctional in intimate relationships later in life as the person grows up and the social environment changes (Lyons-Ruth et al., 1999). Grandparents and older adults can therefore not be expected to be naturally able to provide mutual care to the younger generation. Their dysfunctional internal working models with decreased or lacking capacity for empathy and compassion may be socially transmitted to the next generation. However, internal working models are not carved in stone, which is addressed next.

Recent evidence from neuropsychology and related fields highlight the **plasticity** of the human brain. For example, individuals suffering from brain damage can partially or fully compensate for the loss of certain abilities by training their brain to transfer lost functions to intact cells (Röder, 2016). Furthermore, studies suggest that even when certain time frames facilitate the acquisition of specific skills, these skills can still be learned at later phases, but the effort may be greater (Madeja & Müller-Jung, 2016). For example, a new language is learned readily at a young age, but can be learned at an older age just with more difficulty. Linking these mechanisms to the field of **psychotherapy**, plasticity based interventions can successfully alter dysfunctional internal working models. Facilitating positive social interactions and specifically implementing and training new behavioural patterns can significantly reduce emotional and behavioural problems in patients with dysfunctional internal working models (for example, see ego-state therapy, dialectic behavioural therapy, or schema therapy). Dysfunctional here means that behavioural strategies based on past experiences hamper positive social experiences in the current environment the person lives. Being self-centred, reacting impulsively or being withdrawn may have been compulsive strategies to survive physically or mentally at a young age, but are not as resourceful once the person has grown. In current therapeutic approaches, the strategies developed at a young age are at first highly valued as necessary to survive as a child. The next step is then to adapt the strategies to the current (adult) environment the person lives in (Kaul & Fischer, 2016). These approaches do not only apply to psychotherapy. They could be extended to broader programs for example at schools or family intervention programs. The seemingly never-ending viscous circle of poor early social experiences and their transmission to the next generation can be discontinued if older adults change their dysfunctional internal working models and help the younger generation to develop functional ones.

To conclude, psychological approaches such as learning, attachment, and psychotherapy provide further refinement to understanding why human individuals are (not) able to engage in mutual care on a proximate level. In addition, and what makes these approaches especially valuable, they provide applicable tools to improve dysfunctional internal working models at the individual and family level. These tools could be adapted to interventions applied to broader communities as well.

After having extended the empirical findings to practical approaches in psychotherapy, the focus returns to the understudied male side of caregiving and its potential implications for grandfathers' health.

3.2.4 Future research on grandfathers' health

Studying grandfather involvement has just recently caught scientific attention. Little is yet known about why and how contemporary grandfathers fill this new niche in industrialised societies. First evidence suggests that grandfathers play an independent and different role than grandmothers (Knudsen, 2012). Thus, do grandfathers benefit from caregiving in a different way than their female counterparts? Do grandfathers benefit at all?

One study looking at several aspects of subjective wellbeing found that grandmothers' wellbeing benefited significantly stronger from a positive relationship with their adult grandchildren than the grandfathers' wellbeing did (Mahne & Huxhold, 2015). Other studies have found evidence for beneficial effects of grandfathering on grandfathers' health. For example, Grundy and colleagues (2012) found in their longitudinal study that grandfathers providing the same amount of childcare as grandmothers, had better life satisfaction two years later. In addition, those grandfathers who provided material help showed better self-rated functional health at the follow-up than those who did not provide material help. In a recent study, Bates and Taylor (2016) investigated which dimensions of grandfather involvement mattered regarding their impact on grandfathers' depressive symptoms. The authors found, for example, that recreational activities and grandfathers' commitment were negatively associated with depressive symptoms. Furthermore, they found that too much contact negatively impacted grandfathers' mental health. This finding is in line with the proposed curvilinear association between grandparenting and grandparental health (Coall & Hertwig, 2010). However, the study did not distinguish between biological and non-biological grandfathers. Interdisciplinary approaches may provide a more detailed picture of how grandfather involvement affects grandfathers' physical and mental health.

Considering that the life expectancy has risen for both women and men, this new line of research should identify specific factors and conditions (e.g., custodial care vs. lower levels of care) affecting grandfathers' health. Moreover, how would older men who are not grandfathers potentially benefit from childcare involvement beyond the family? From an interdisciplinary point of view, future research in this area should take advanced approaches across disciplines into account.

After describing, testing, and evaluating the interdisciplinary perspectives presented in this framework, I would like to add a personal conclusion at the end.

3.3 Conclusion: A plea for mutual care

Biological relatedness alone is a surprisingly unreliable predictor of love (Hrdy, 2001). In a study observing average middle class children encountering no obvious risk factors, Lyons-Ruth and colleagues (1999) found that about 15 percent were not capable of finding comfort and trust in the arms of their primary caregivers. Lacking the experience of trust and mutual care, these children were not projected to learn how to provide mutual care to their own future children. Thus, their dysfunctional internal working models would be transmitted to the next generation. Looking for opportunities to give and receive love and mutual care outside the biological family may therefore be a good idea for these children. This opens the stage for allomothers to engage in prosocial behaviour and support the younger generation in the development of mutual care. That is, non-biological grandparents and older individuals without children in particular are called to step in; provided that these allomothers are capable of expressing mutual care themselves. If yes, the result is then, as shown in this framework, a win-win situation with benefits for both, the care provider and receiver.

In light of these benefits, the question may arise whether or not caregiving can be called altruistic. Reviewing the scientific debate on altruism would go far beyond the scope of this framework (for a review, see Kurzban et al., 2015). The point here is that caregiving may be ultimately rooted in ancient parenting and grandparenting, expanded to the capacity for empathy and compassion towards non-kin and even other species such as animals or plants – independent of reciprocity. Nevertheless, mutual care needs to be self-experienced in order to be transmitted into future generations. In ancient times, a baby born without dedicated caregivers was unlikely to survive and the lacking capacity for mutual care was not transmitted further. This is different today. For the first time in human history, many women decide not to have children, but those children born in industrialised societies are most likely to survive and reproduce themselves (Hrdy, 2009), regardless of the emotional quality in the relationships with their caretakers. Thus, the call for allomothers assisting parents with childrearing, thereby enabling the experience of mutual care for the next generation, is of great importance for the future of our species. With this in mind, the ongoing demographic change has two faces: On the one side, the increase of female labour force participation, divorce rates, and mobility puts pressure on parents' resources to provide mutual care. On the other side, these same factors offer new forms of family structure that move away from the stereotypical nuclear family (mom caring, dad ensuring material security) and provide space for allomothers to step in.

In the beginning of this framework I quoted Sarah Bluffer Hrdy who in her book "Mothers and others" (2009) demonstrated very comprehensively how human cooperation may have evolved over millions of years. I was deeply touched by her scientific based arguments on empathy and compassion. Through my work as a psychotherapist, treating individuals suffering from trauma and/or personality disorders, I have had a glimpse into what happens when the flawed or complete lack of capacity for mutual care is socially transmitted from one generation to the next. In reading Sarah's book, I suddenly understood the broader bearing for our species if we as individuals do not promote this uniquely well developed trait in our children. Sarah stated her worries that the capacity for empathy and compassion may just fade away over the next thousands of generations like sight in fish living and reproducing in dark caves for multiple generations.

However, in my experience as a psychotherapist, I do believe in the plasticity of the human brain. Even if we did not encounter rearing conditions fostering our capacity for compassion when we were young, this lack can be compensated – at least to some degree – later in life. After all, each and every one of us has to decide whether or not we practice (or learn to practice) mutual care, how compassionately and socially engaged we live our lives, and how we contribute to the wellbeing of ourselves and others in society. This argument, in fact, is not very new. There are multiple spiritual practices, for example in Buddhism, suggesting to focus on practicing compassion in order to unfold our capacity for love and mutual care (e.g., Salzberg, 2003).

In this spirit, I would like to close this framework by proposing the following answer to the question asked in the title:

Why Care?

Because we are not cave-dwelling fish.

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5. Appendices

5.1 Appendix A: Manuscript 1

Predictors of Grandparental Investment Decisions in Contemporary Europe:

Biological Relatedness and Beyond

David A. Coall[1,2], Sonja Hilbrand[3], Ralph Hertwig[4]

[1] School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

[2] School of Psychiatry and Clinical Neurosciences, University of Western Australia, Crawley, WA, Australia

[3] Faculty of Psychology, University of Basel, Basel, Switzerland

[4] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

Correspondence concerning this article should be addressed to David A. Coall, School of Medical and Health Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup, Western Australia 6027. Tel: +61 8 6304 2118; E-mail: d.coall@ecu.edu.au

Abstract

Across human cultures, grandparents make a valued contribution to the health of their families and communities. Moreover, evidence is gathering that grandparents have a positive impact on the development of grandchildren in contemporary industrialized societies. A broad range of factors that influence the likelihood grandparents will invest in their grandchildren has been explored by disciplines as diverse as sociology, economics, psychology and evolutionary biology. To progress toward an encompassing framework, this study will include biological relatedness between grandparents and grandchildren, a factor central to some discipline's theoretical frameworks (e.g., evolutionary biology), next to a wide range of other factors in an analysis of grandparental investment in contemporary Europe. This study draws on data collected in the Survey of Health, Ageing and Retirement in Europe from 11 European countries that included 22,967 grandparent–child dyads. Grandparents reported biological relatedness, and grandparental investment was measured as the frequency of informal childcare. Biological and non-biological grandparents differed significantly in a variety of individual, familial and area-level characteristics. Furthermore, many other economic, sociological, and psychological factors also influenced grandparental investment. When they were controlled, biological grandparents, relative to non-biological grandparents, were more likely to invest heavily, looking after their grandchildren *almost daily* or *weekly*. Paradoxically, however, they were also more likely to invest nothing at all. We discuss the methodological and theoretical implications of these findings across disciplines.

Key words: Grandparental investment, biological relatedness, intergenerational solidarity, filial expectations

Introduction

Across human cultures, grandparents and elders more generally are respected and valued contributors to the health of their families and communities. Disciplines as diverse as sociology, economics, psychology, and evolutionary biology and psychology have documented the impact grandparents have within families. Evidence from traditional societies shows that the presence of a grandparent can be as beneficial to child survival as, for instance, the introduction of a new water supply [1,2]. In industrialized nations, the evidence is mounting that—especially in family environments with low resource availability—grandparents can buffer child development against difficult early environments [3,4]. At the same time, however, millions of grandparents invest nothing—possibly because they are physically or emotionally remote or because they lack the necessary resources or inclination. All of the disciplines mentioned above seek to understand this variability, asking the questions: Why do (or do not) grandparents invest in their grandchildren? And what factors impact the levels of investment they provide?

With rapidly changing family structures in most industrialized nations and a concomitant change in the potential role of grandparents, grandparental investment is a burgeoning field of investigation. Yet although it cuts across several disciplines, there has to date been little cross-disciplinary research. Strong disciplinary barriers, misconceptions between disciplines, and exaggeration of disciplines' views have limited progress in the field [5]. While it is patent that each discipline makes valuable contributions to the study of grandparental investment, real progress in the field requires a comprehensive approach to grandparental investment. Against this background, we draw on an international database of older people to examine the contribution that evolutionary (biological), economic (macro- and micro-economic), demographic (fertility), sociological (region, intergenerational solidarity), and psychological (relationships, beliefs, and expectations) factors make to grandparents' inclination to invest in their grandchildren.

In the following we briefly review previous findings concerning factors impacting grandparental investment. Before we begin, let us clarify that with a few exceptions, it is impossible to confine a given variable or factor to a single theoretical perspective. Consider, for example, the variable used in this study: informal childcare provided by grandparents. Depending on the discipline's perspective, this variable can be described as intergenerational transfer (economic, evolutionary, and demographic perspectives), intergenerational solidarity (sociology), instrumental social support (psychology), or childcare (economics). Thus, one has to be careful in trying to categorize variables by discipline. Relatedly, a focus on one variable does not exclude, indeed often demands, the consideration of many other moderating variables. For instance, the focus on biological relatedness also necessitates the analysis of the impact of post-marital affiliations, lineage, sex and age of grandparents and grandchildren, family size, and characteristics of the environment (in this case, familial, economic, regional, and social [6,7,8,9]).

Does biological relatedness impact grandparental investment?

Perhaps the most controversial and divisive issue between disciplines investigating grandparental investment is the role of biological relatedness [10]. The question other disciplines would ask of the evolutionary perspective is timely: Is the biological relationship between family members still relevant in contemporary societies? In industrialized societies, falling rates of marriage and high rates of divorce and remarriage have led to an increase in the proportion of non-kin, including grandparents, in many families. In 2009, for instance, the U.S. marriage rate was 6.8 per 1,000 people, with a divorce rate of 3.4 per 1,000 people [11]. After separation, 25% of women, who are more likely to have custody of their children, repartner within 2 years and remarry within 5 years [12]. Do the new, non-biological grandparents provide childcare equivalent to that provided by biological grandparents? Alternatively, do they invest less than biological grandparents, or are they wholly disengaged? To find out, we draw on an international database to examine the differences in informal childcare provided by grandparents who are or are not biologically related to their grandchildren.

Biological relatedness within a family matters. For instance, there is considerable evidence that closer biological relationships (and closer attachment) between children and family caregivers are associated with increased investment behaviors [13,14,15] and perceived obligations to those kin [16]. The impact of biological relatedness has been demonstrated in several lines of research. One, kin selection theory—the notion that inclusive fitness benefits stemming from the genetic relationship shared between grandparents and grandchildren lead grandparents to care for their grandchildren—attributes that behavior to the 25% shared biological relationship between grandparents and grandchildren. Recently, calls have been made to introduce genetic relatedness into cross-disciplinary studies for a more comprehensive understanding of grandparental investment [17]. We agree but also believe that the following question needs to be addressed: Can individuals' values such as filial expectations that are associated with grandparenthood [3,5] compensate for the lack of biological relatedness?

Quality relationships with biological grandparents—associated with improved emotional health of grandchildren across nuclear, step-parent, and single-parent families [18]—cannot be taken for granted. Paternal grandparents may, for instance, become alienated after divorce, when the father typically leaves the household. Although maintaining quality contact with paternal grandparents after re-marriage and step-family formation appears to be beneficial to the behavioral adjustment and mental health of both grandparents and grandchildren [19,20,21], we know little about the role non-biological grandparents (e.g., the step-father's parents) play in childcare and grandchildren's development. Circumstantial evidence supports the idea that—in analogy to step-parent families [14]—the relationship between step-grandparents and grandchildren is less advantageous to grandchildren than is their relationship with biological grandparents [22,23,24]. These preliminary findings are consistent with the thesis that step-grandparents are less inclined than biological grandparents to invest in their grandchildren. This thesis, however, has never been tested. Moreover, the datasets used to examine factors associated with grandparental investment are often limited to kin grandparent–grandchild dyads [25,26,27]. Our goal with the present study is to address the investment behavior of both biological and non-biological grandparents.

Sex and lineage effects of grandparents

Conceiving all grandparents, biological or non-biological, as equal investors would be naïve: Evidence from the sociological, psychological, and evolutionary literature suggests that different types of grandparents show different investment patterns [3,28]. Perhaps, the most robust pattern is that maternal grandmothers invest the most, followed by maternal grandfathers, then paternal grandmothers, with paternal grandfathers investing the least. Different explanations exist. Sociological theorizing holds that women are kin-keepers, holding kin groups together [29,30]. Similarly, according to family systems theory, it is the gatekeeper role of the parent (middle) generation that encourages (or not) the grandparent–grandchild relationship [16]. Thus, if the grandparent and parent are female (e.g., maternal grandmother), the bond between grandparent and grandchild will be stronger than if they were male (e.g., paternal grandfather), resulting in the pattern described. Evolutionary perspectives attribute this association between grandparent type and investment to sex-specific reproductive strategies and paternity uncertainty (see Table 1 in [3]). Whereas women are 100% certain who their children are, males are generally less than 100% certain that they are the biological father of their children. Grandparents with higher levels of certainty of their biological relationship to their grandchildren (maternal grandparents) invest more than those with lower levels of certainty (paternal grandparents; see [26,31,32]). Finally, from a psychological perspective, it has been proposed that this pattern may result from the well-known differences in age and life expectancy between grandparent types [33]. These different perspectives make similar and largely compatible predictions [34,35] even though they focus on different levels of explanation (i.e., mechanistic versus adaptationist).

Numerous non-biological factors drive investment decisions

The investment decisions made by biological and non-biological grandparents are of course not necessarily due to differences in biological relatedness. Other factors may also impact investment. For instance, a non-biological grandparent whose child has divorced and remarried may be older or less healthy, have more children and grandchildren, have fewer resources to invest, feel less obligation to the family, or live further away from his/her grandchildren. Such factors would affect the availability of grandparental resources and may be more pronounced in non-biological grandparents. Indeed, this is where the predictions of evolutionary models diverge from those of economic and sociological perspectives [5] such as the *rational grandparent* model [28]. This model holds that grandparental investment is indifferent to biological relatedness and that grandparents will preferentially invest in those descendants who are most likely to reciprocate in the future.

Next to these individual characteristics, it is also important to consider macroeconomic factors potentially impacting grandparental investment, such as the interaction between welfare-state systems and grandparental investment. Using the Survey of Health, Ageing and Retirement (SHARE), one study found a north–south gradient in grandparental childcare [36]. Danish, Dutch, French, and Swedish grandparents were more likely to provide any care for their grandchildren but were less likely to provide it regularly. Austrian, German, and Swiss grandparents showed average levels of both any care and regular care. In Greece, Italy, and Spain, grandparents were less likely to provide any care, but when they did, it was more likely to be regular. The authors suggested that the higher availability of state-provided childcare in northern European countries promotes maternal employment, meaning that grandparents are needed to supplement institutional care. Conversely, in Mediterranean countries, where state-run childcare is less widespread and more expensive, levels of maternal employment are lower. If the mother is employed, however, grandparents become regular childcare providers [37,38]. Sear and Coall [4] investigated the implications of this association further and found that low levels of regular care and high levels of any care were strongly associated with higher fertility rates across Europe. Thus, regional differences in state-provided childcare and female employment rates, which may be reflected in national fertility rates, also have consequences for the grandparental investment in contemporary industrialized nations. In this study, we will use national fertility rates as a course proxy for these macroeconomic factors.

Of course, not all differences in grandparental investment between regions of Europe are associated with welfare state regimes, the role of women in the workforce, and thus national fertility rates. Regional preferences, independent of macro-economic factors, are likely to also influence grandparental investment. Kaptijn and Thomese [39] highlighted the Netherlands as an example of this: the joint presence of parental preferences for grandparents as childcare providers and high availability of state-funded childcare in the Netherlands suggests that, in some circumstances, regional preferences (values) have the power to outweigh macro-economic influences. In the present study, regions of Europe (north/central and south/central) will be used to examine the potential influence of regional differences on grandparental investment across Europe.

In sum, we investigate three issues: (1) Does biological relatedness influence grandparental investment patterns in contemporary Europe? (2) Do various non-biological factors—that is, age, health, sex, lineage, distance, family size, employment, marital status, family obligations and conflict, geographic regions, and fertility rates—vary between biological and non-biological grandparents and influence their investment decisions? (3) Assuming that non-biological and biological grandparents differ systematically on non-biological factors, do these differences fully account for differential investment patterns of non-biological and biological grandparents—or is biological relatedness an indispensable explanatory factor in contemporary Europe? In order to study these questions, we drew on data from the large-scale international dataset collected in the context of the Survey of Health, Ageing and Retirement in Europe (SHARE).

Methods

Sample

Our empirical analysis was based on the first wave of the multidisciplinary SHARE project, which was conducted in 2004. Data were collected across 12 countries from a representative sample of participants aged 50 or older and their partners. A computer-assisted interview and paper-and-pencil questionnaire covered aging-related topics such as health, social and family networks, and financial situation (for details, see [40]). In the present investigation, the sample was restricted to European respondents (generation 1: grandparents; G1) from Austria, Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Spain, Sweden, and Switzerland who had either biological or non-biological children (generation 2: children; G2) (to a maximum of four children) and at least one grandchild (generation 3: grandchildren; G3) (not older than 14 years). On average, each respondent (G1) had 2.7 children (G2) and 4.0 grandchildren (G3). To examine each grandparent–child relationship (G1–G2), the dataset was transformed into 22,967 observations representing 12,959 grandmother–child dyads (56.4%) and 10,008 grandfather–child dyads (43.6%). Of the total dyads, 2257 were non-biological (9.8%).

It is important to note that we explore grandparents' (G1) investment in grandchildren (G3) through the grandparent–child (G1–G2) dyad. As such, most of the variables explored, including biological relatedness, reflect the grandparent–child relationship. Information on the sex of grandchildren (G3) and their biological relationship to their parents (G2) were not available in the SHARE dataset. A detailed overview of the descriptive data is available as Supporting Information (SI, see Table S1).

Measures

Grandparental investment, the dependent variable, was measured by integrating responses to two questions. First, grandparents (G1) were asked whether they had looked after their grandchildren (G3) in the past twelve months, with the response categories 'Yes' and 'No'. Second, those participants (G1) who answered positively were then asked, independently of their spouse, how often they had looked after their grandchildren (G3) without the presence of the parents (G2) in the last twelve months. This question is of particular value as a measure of investment, because looking after grandchildren without the presence of the parents provides resources to the parents (G2) [41] and has opportunity costs for the grandparents (G1) [42]. Thus, it is a clear measure of grandparental investment in terms of the instrumental support or tangible benefits provided to the family. The answers to the two questions were merged to produce a 5-point ranking scale of grandparental investment: almost daily (5), almost weekly (4), almost monthly (3), less often (2), and never (1).

The *biological* versus *non-biological grandparent* variable was determined from the following question addressed to grandparents (G1): "Is this child a natural child/Are all these children natural children of your own [and your current spouse or partner]"? From the responses to this question, grandparents were categorized as being either biologically related to all or none of the children (G2) they were questioned about. Parents (G1) who are not biologically related to their children (G2) cannot, by extension, be related to their grandchildren (G3) by those children. This process established the biological relatedness of each grandparent–child dyad (G1–G2). Grandparents' answers were recoded into 0 (non-biological grandparent) or 1 (biological grandparent).

Grandparent's *sex* was coded as 0 (grandfather) or 1 (grandmother). The sex of the child (G2) was used to compute the *lineage* variable that denotes for each grandparent–child dyad whether a grandparent is paternal (0) or maternal (1). Assuming that grandchildren (G3) under the age of 14 usually live with their parents (G2), *distance* to each (grand)child was measured on a 9-point scale, ranging from living "in the same household" to "more than 500 kilometers away, abroad." There was no question directly probing how far grandparents lived from their grandchildren. *Number of children* (G2) *and grandchildren* (G3) was directly extracted from the original SHARE variables. *Age* of grandparents, children, and grandchildren was computed by subtracting the year of birth from the year that the interview was conducted. The 5-point scale of grandparental *health* was reverse coded to range from 1 (very bad) to 5 (very good).

The variable *filial expectations* subsumed four items probing grandparents' endorsement of statements relating to family obligations and grandparenting roles: (1) "Parents' duty is to do their best for their children even at the expense of their own well-being"; (2) "Grandparents' duty is to be there for grandchildren in cases of difficulty (such as divorce of parents or illness)"; (3) "Grandparents' duty is to contribute towards the economic security of grandchildren and their families"; and (4) "Grandparents' duty is to help grandchildren's parents in looking after young grandchildren." For each grandparent, a composite score was calculated by averaging the four responses (given on a 5-point scale that we reverse coded to range from 1 = "very low" to 5 = "very high"). The scale had good internal consistency, with a Cronbach's alpha coefficient of .78.

Two questions concerned *conflicts with children* (G2). The first, general question read: "There are sometimes important questions about which we have a disagreement with persons close to us, and which therefore may lead to conflicts. Please tell us how often, if at all, you experience conflict with each of the following persons: d) children" (the other options are not relevant to the present analysis). The second, more specific question asked about conflicts over the *upbringing of grandchildren*: "How often do you experience conflicts with your children or children-in-law over the education and bringing up of your grandchild(ren)?". The four response alternatives to each question were dichotomized into two groups: *low* ("rarely," "never") and *high* ("often," "sometimes") conflict.

Bank *savings* in euro was used as a proxy for grandparents' financial status. Concerning grandparents' (G1) and children's (G2) *education*, SHARE provides standard coding for international comparisons (ISCED-97), where a higher category number (1–19) indicates a higher educational level. Data on the working and partner status of grandparents (G1) and children (G2) were dichotomized into *gainfully working* or not and *living with a partner* or not. The categorical variable *regions* was computed with reference to the findings of Hank and Buber [36], who found a north–south gradient in grandparental childcare in Europe using the SHARE database. Our variable therefore distinguishes between the *north/central* (1) region (Sweden, Denmark, France, Belgium, Netherlands, and Germany) and the *south/central* (0) region of Europe (Austria, Switzerland, Italy, Spain, and Greece). Finally, *fertility rates* from 2004 were obtained electronically from the Population Reference Bureau [43] and added to the database manually for each country. These figures show the average total number of children a woman will have at current age-specific birth rates. Compared with other regions of the world, the fertility rates of all countries in our sample are low, ranging from 1.32 to 1.92. However, there is a gradient reflecting the north–south axis through Europe, with the lowest fertility rates in Italy and Greece and the highest in France, Denmark, and Sweden (for details, see Table S1 in the SI).

Data analysis

The data analysis proceeded in four main steps. First, we analyzed whether biological and non-biological grandparents differed in levels of grandparental investment as well as in various non-biological factors (see Table 1). Categorical variables were analyzed with chi-square tests (with Yates' correction for continuity) and continuous variables with Mann–Whitney U tests. Second, we additionally used Spearman correlations to analyze whether grandparents' non-biological characteristics varied according to their level of investment and therefore were identified as confounders (see Table S3 in the SI). Third, we used multinomial logistic regression to examine whether any effect of biological relatedness (or lack thereof) on the level of grandparental investment could be explained by variation in non-biological grandparental characteristics. Grandparental investment levels were used as the dependent variable and the characteristics as covariates (see Table 2; Table S6 in the SI). Accounting for the clustered structure of the data, we used a *household identifier* provided by SHARE to control for grandparent–child dyads (G1–G2) originating from the same grandparents. The household identifier, scrambling coding of the country, household and personal record number for each grandparent (13 digits), was sorted in ascending order and included as control variable in the regression model. Geographic clusters were controlled by the variable *regions*.

Multinomial logistic regression allowed us to analyze each level of an ordinal outcome variable relative to the reference level. The reference level in this study was *no investment*. For each of the remaining investment levels (*almost daily*, *almost weekly*, *almost monthly*, and *less often*), the variance explained by each covariate was tested for significance in relation to *no investment* (odds ratio). Furthermore, the estimated probabilities for each investment level can be calculated and saved as a new variable in the database. Only true confounders were included in the regression model, that is, those covariates that are significantly associated with both biological relatedness and grandparental investment, and that therefore potentially account for the variance between the two variables (see Table S3 in the SI). The one exception was the covariate *lineage* (and therefore sex of child). Statistically, there was no association with biological relatedness, which is easily explained: a child's sex cannot be expected to be dependent on whether or not the parent is a biological relative. However, there was a strong association with investment, as expected from several theoretical perspectives. This important covariate was therefore included in the final model. The assumptions for multinomial logistic regression, such as sample size, multicollinearity, and outliers were met, and the potential mediator effect of age on health was examined (see Table S4 in the SI).

Taking advantage of the multinational SHARE database, we examined the independent influence of geographic regions and fertility rates separately. Both covariates were found to be independent predictors of grandparental investment and were used in subsequent analyses. Further information on the use of these country-specific parameters is included in the Supporting Information (Table S5 in the SI). Before running the final analysis, we tested the results for robustness (see Tables S7, S8, and S9 in the SI). In addition, we examined whether grandparents who looked after their grandchildren on a daily basis were in fact probably substitute parents, as SHARE does not provide information about custodial care (Table S2 in the SI).

As the final step of the analysis, we conducted a mixed between-within subjects analysis of variance (Figure 1), and tested the effect of being a biological versus non-biological grandparent across all investment levels, including no investment, instead of relative to it (Figure 1). Furthermore, this procedure allowed us to evaluate the mean differences and to test for interactions between biological and non-biological grandparent variables and investment levels. The dependent variable *probability of grandparental investment* includes the influence of the true confounders, as estimated probabilities for each investment level were saved from the previous multinomial logistic regression procedure.

Results

Does biological relatedness influence grandparental investment?

First and foremost, were there any differences in the investment of biological and non-biological grandparents? Yes, there were. Specifically, the proportion of biological grandparents reporting investment on a daily basis was more than double that of non-biological grandparents (8.8% versus 3.8%, see Table 1). Likewise, more biological than non-biological grandparents looked after their grandchildren on a weekly basis (15.5% versus 11.4%). However, more non-biological than biological grandparents reported investment on a monthly basis or less often, and around 50% of both groups reported no investment at all. These differences in investment could be due to non-biological factors, biological relatedness, or a combination of both. The following analyses aim to determine the relative contribution of these factors.

Table 1. Individual, familial and macro-economic characteristics of biological and non-biological grandparents [a]

	Biological (n = 20,710)			Non-biological (n = 2257)			
	Mean (%[b])	SD[c]	n	Mean (%[b])	SD[c]	n	p
Almost daily childcare	8.8		1819	3.8		85	***
Almost weekly childcare	15.5		3210	11.4		256	**
Almost monthly childcare	10.6		2186	12.9		289	*
Less often childcare	15.0		3103	19.9		448	**
Never childcare	50.1		10356	52.0		1170	*
Grandparent sex (female)	57.6		11934	45.4		1025	***
Grandparent lineage (maternal)	50.8		10523	50.5		1140	
Filial expectations	3.8	0.8	13743	3.6	0.8	1600	***
Distance to (grand)child	4.7	1.9	20681	5.2	2.0	2230	***
Number of children	2.6	0.9	20710	3.0	0.9	2257	***
Number of grandchildren	3.9	2.6	20710	4.2	3.0	2257	*
Grandparent’s age	68.5	9.8	20702	63.8	9.1	2257	***
Grandparent’s health	3.5	0.9	10131	3.7	1.0	1130	***
Conflict with children (high)	28.9		3785	29.9		451	
Conflict about grandchildren’s upbringing (high)	12.8		1626	8.7		124	***
Savings (in euro)	19800	643656	7722	35498	196906	1106	
Grandparent’s education	4.4	4.9	18815	4.9	4.7	2170	***
Grandparent employed (yes)	30.2		4890	29.4		541	
Grandparent has a partner (yes)	61.0		12641	78.0		1761	***
Age of child	36.8	9.7	20533	32.3	10.6	2240	***
Education of child	5.7	4.8	19609	6.0	4.5	2084	***
Child employed (yes)	78.9		16059	72.8		1517	***
Child has a partner (yes)	75.4		14857	74.3		1397	
Age of youngest grandchild	10.1	8.5	12654	8.7	8.1	1143	***
Fertility rates	1.5	0.2	20710	1.7	0.2	2257	***
Regions (north/central)	60.9		12617	87.1		1966	***

[a] Statistical comparisons between biological and non-biological grandparents were made using chi-square or Mann–Whitney U tests

[b] percentage is shown for categorical variables

[c] standard deviation is absent for categorical variables

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

Which factors contribute to grandparents' investment decisions?

We examined on which non-biological characteristics grandparents, their children and grandchildren differed as a function of whether the grandparent was biologically related to the grandchild's parent (G2). Table 1 lists the results. In fact, the majority of characteristics varied significantly between biological and non-biological grandparents. To begin with, a significantly larger proportion of biological than non-biological grandparents in the sample were grandmothers; however, there was no difference in the proportion of grandparents who were maternal versus paternal. Next, biological grandparents felt significantly more obliged to help their family than did non-biological grandparents. Furthermore, biological grandparents lived closer and had fewer children and grandchildren than did non-biological grandparents. A higher sense of duty, closer proximity, and fewer recipients of their investment could all contribute to making biological grandparents higher investors.

However, other differences are likely to deplete the resources of biological grandparents or make them less inclined to invest, relative to non-biological grandparents. Specifically, biological grandparents were older, reported poorer health and lower educational attainment, and were less likely to have a partner than non-biological grandparents. Furthermore, biological grandparents reported more conflicts with their children (G2) about the upbringing of their grandchildren than did non-biological grandparents; however, there was no difference in conflicts with children generally. The biological grandparents in the sample were less likely to be from the north/central region of Europe and exhibited the associated lower fertility rates. Some country-specific structural and regional factors that may be reflected in fertility rates and geographic borders therefore seem to affect the chance of becoming a non-biological grandparent, which may further impact the level of grandparental investment. In terms of financial status, there were no differences in the amount of savings grandparents had or their likelihood of employment. Last but not least, there were some differences between the children of biological and non-biological grandparents. The children of biological grandparents were older, had lower educational attainment, and were more likely to be employed. There was no difference in the proportion of children having a partner.

In sum, numerous significant differences between biological and non-biological grandparents were observed. Some of these differences are likely to favor higher investments by biological than non-biological grandparents (e.g., sense of obligation, smaller distances), whereas others impede higher investments (e.g., older age, poorer health). In light of these results, we next examined which grandparental characteristics, across biological and non-biological grandparents together, were significantly associated with high grandparental investment (Table S3 in the SI). In combination with the initial analysis (Table 1), we thus established true confounders of the relationship between biological relatedness and grandparental investment by identifying those characteristics associated with both variables. Before turning to this analysis, we examined whether there was any indication that grandparents who looked after their grandchildren on a daily basis were substitute parents. There was no evidence that this was the case (Table S2 in the SI), suggesting that daily investment exacts opportunity costs for the grandparents and is therefore a genuine measure of investment.

Do non-biological factors account for the biological relatedness effect?

All true confounders plus lineage and a variable controlling for households were entered into a multinomial logistic regression to determine whether the association between biological relatedness and grandparental investment was an independent effect or could be accounted for by one or several grandparent characteristics. Table 2 shows which of the covariates significantly explained variance in each of the grandparental investment levels relative to the reference level (no investment). Odds ratios and significance levels of covariates are given for each investment level. Table S6 in the SI presents more statistical details.

Table 2. Odds ratios (Exp[B]) and significance levels for each grandparental investment level: results of a multinomial logistic regression analysis

	Almost daily childcare		Almost weekly childcare		Almost monthly childcare		Less often childcare	
	Exp(B)	p	Exp(B)	p	Exp(B)	p	Exp(B)	p
Biological grandparent (yes)	1.51	*	1.57	*	0.98		1.10	
Grandparent sex (female)	1.24		1.22		1.31	*	1.29	*
Grandparent lineage (maternal)	1.54	**	1.06		0.83		1.07	
Filial expectations	1.79	***	1.24	**	1.46	***	1.09	
Distance to (grand)child	0.71	***	0.79	***	0.98		1.14	***
Number of children	0.71	**	0.97		1.11		1.20	*
Number of grandchildren	1.08	*	1.04		1.00		0.98	
Grandparent's age	0.92	***	0.93	***	0.93	***	0.96	***
Grandparent's health	0.83	*	1.18	**	1.10		1.23	***
Conflict about grandchildren's upbringing (high)	1.18		0.86		0.87		0.84	
Grandparent's education	1.01		1.09	***	1.09	**	1.05	
Grandparent has a partner (yes)	1.79	***	1.38	**	1.14		0.93	
Age of child	0.93	***	0.94	***	0.97	*	0.97	*
Education of child	1.09	**	1.00		0.93	*	0.97	
Child employed (yes)	1.95	***	1.08		1.37	*	1.05	
Age of youngest grandchild	0.91	***	0.92	***	0.90	***	0.93	***
Fertility rates	0.13	**	0.81		4.02	**	5.41	***
Regions (north/central)	0.43	**	1.13		1.66	*	1.03	
Household identifier	0.97		0.96		0.99		1.00	

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

Biological grandparents were 1.5 times as likely as non-biological grandparents to invest on a daily ($p < .04$) or weekly basis ($p < .02$), relative to non-investors. There was no significant difference between these two groups at the level of monthly or less frequent investment. The variance explained by the total model was high, with a Nagelkerke's R^2 of 44.5%.

Key findings with respect to the covariates include consistent positive associations between filial expectations and the probability of grandparental investment on a daily, weekly, and monthly basis. Moreover, younger grandparents were more likely to invest, and younger children and grandchildren were more likely to receive investment, across all levels of investment. For other variables, the association changed with investment level. Children of working parents (G2) were more likely to receive grandparental care on a daily and monthly basis. Greater geographical distance to grandchildren was associated with lower investment on a daily and weekly level, but higher investment on a less frequent basis. Having more children reduced the likelihood of daily investment, but increased the probability of investment on a less frequent basis. Interestingly, having more grandchildren *increased* the likelihood of daily investment. Higher fertility rates were associated with a significantly decreased likelihood of grandparents looking after their grandchildren on a daily basis, but a strongly increased probability of grandparental care on a monthly and less frequent basis. Living in north/central Europe significantly decreased the chance of daily investment, but increased the chance of investment on a monthly basis. Both variables indicate more frequent grandparental investment in the southern countries, where fertility rates are lower than in the north. These results are in line with the results of Hank and Buber [36], who found that grandparental investment is prevalent across Europe, but more intense in the southern countries.

We tested the robustness of these results by using different statistical methods and altering the categorization of grandparental investment. Similar results emerged when we used binary logistic regression and dichotomized the investment variable into high (almost daily/weekly) and low (almost monthly/less often/never) investment. Moreover, both multinomial and binary logistic regression still produced similar results when all the non-investors (50.3% of the sample) were excluded, suggesting that these are robust effects. The results of these additional analyses are available in Tables S7, S8, and S9 in the SI.

Grandparental paradox: Biological grandparents invest heavily or not at all

Finally, we examined the mean differences between biological and non-biological grandparents in the estimated probabilities of grandparental investment levels. Figure 1 plots the results by investment levels and grandparental group. When interpreting these results, it is important to bear in mind that this analysis measures mean differences in the probability of grandparental investment, which is not relative to any investment level (as was the case in the multinomial logistic regression). The most striking result is that biological grandparents were significantly more likely than non-biological grandparents to invest at both extremes of the investment spectrum. Biological grandparents were more likely to invest heavily, looking after their grandchildren *almost daily* or *weekly*, but they were also more likely to invest nothing at all. Non-biological grandparents showed a higher probability of investing *almost monthly* or *less often*.

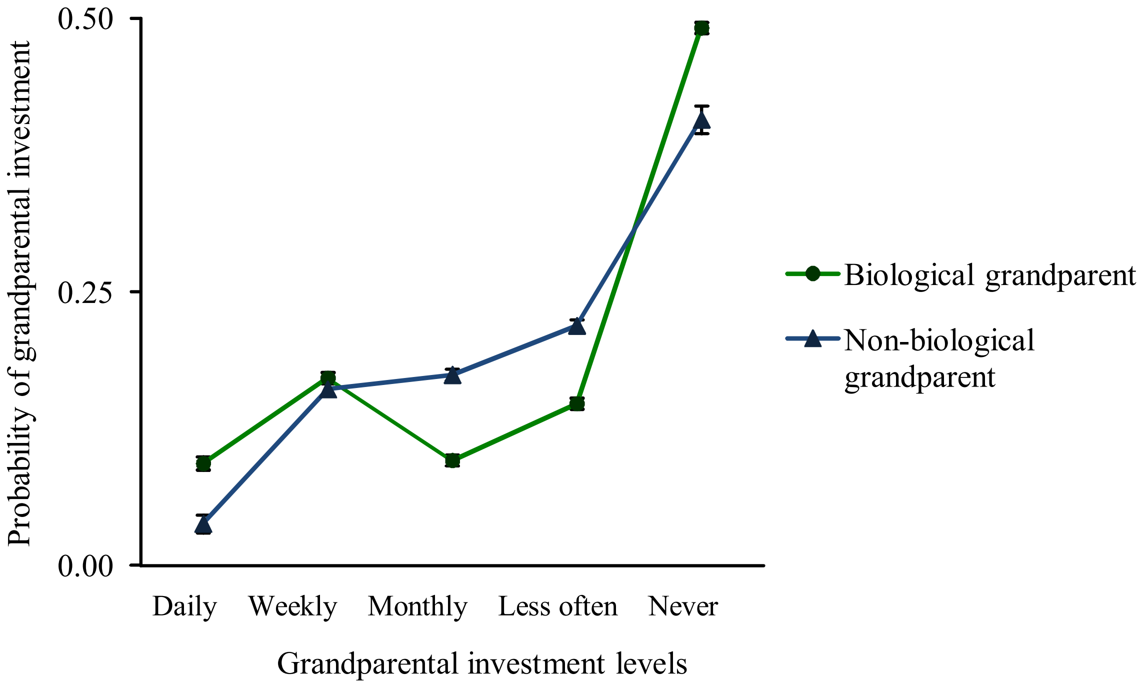

Figure 1. Means and standard errors for the probability of grandparental investment across grandparental investment frequency and biological relatedness

To determine whether the different investment inclinations between biological and non-biological grandparents were significant, we investigated the interaction. The interaction term was significant, showing that the level of investment depended strongly on whether or not the grandparent was biological (Wilks' lambda = .90, $F(4, 3813) = 106.69$, $p < .0005$, partial $\eta^2 = .10$). In this model, the main effect of biological versus non-biological grandparent remained significant ($F(1, 3816) = 277.25$, $p < .0005$, partial $\eta^2 = .07$), as did the main effect of investment level (Wilks' lambda = .50, $F(4, 3813) = 983.35$, $p < .0005$, partial $\eta^2 = .50$).

Discussion

The present investigation is the first to show that the biological relationship between grandparents and grandchildren contributes to variation in grandparental investment in modern European societies, independent of a wide range of non-biological factors. Biological grandparents were more likely than non-biological grandparents to make high investments in their grandchildren. This evidence supports kin selection theory [44], which was previously untested in grandparents. Paradoxically, biological grandparents were also more likely not to invest at all. To our knowledge, this is a unique finding in the grandparental investment literature. We speculate on the potential causes of this association below. Equally important, however, is the finding that a range of non-biological factors impacted grandparents' investment decisions. This finding highlights the need for an encompassing approach in this field: social, economic, psychological, and evolutionary factors all play a role in explaining the variance in grandparental investment behaviors.

How do biological and non-biological grandparents differ?

Central to understanding why biological and non-biological grandparents invest differently in their grandchildren are the dimensions on which they differ (Table 1). Many factors previously associated with increased investment are also correlated with being biologically related to grandchildren [45,46]. Specifically, biological grandparents were more likely to be female, felt more duty to their family, lived closer, had fewer children and grandchildren, and their children were more likely to be employed. On the other hand, biological grandparents also had characteristics commonly associated with reduced investment: They were less healthy and older, as were their children and grandchildren. Moreover, they were less likely to have a partner, and—perhaps because they do invest more—had more conflicts with their children about how their grandchildren are brought up. At the macro-economic level, biological grandparents were more likely to be from south/central European nations with lower average fertility rates. Although these factors accounted for more than 40% of the variance in grandparental investment, they did not fully account for the higher investment by biological grandparents. This relationship was robust to alternate statistical methods and the dichotomization of grandparental childcare into “high” and “low” investment categories [25,36]. Our findings thus suggest that biological relatedness between grandparents and their children remains an important predictor of grandparental investment in contemporary industrialized European societies.

The two faces of investment by biological grandparents

Studies of grandparental investment consistently focus on grandparents who do invest. In light of this focus, it is striking that approximately 50% of biological grandparents did not invest at all, at least not in the form of informal childcare (Figure 1). At this point we can only speculate about the reasons. Biological grandparents may be more likely to experience conflict in the family and thus estrangement. Consistent with this, biological grandparents were significantly more likely than non-biological grandparents to report conflicts about the upbringing of their grandchildren (Table 1). It is also likely that some biological grandparents provide resources other than time. They may be financial—in the form of an inheritance or help with the costs of education—or they may take the form of emotional support. All of these resources are valuable aspects of intergenerational solidarity that we did not consider in the present analysis.

Our results have implications for understanding the "units" in which grandparents invest. Having more children strongly decreases *almost daily* investment, whereas having more grandchildren independently increases investment. This finding suggests that it is specifically the number of family units between which grandparents split their investment that reduces investment, rather than the absolute number of grandchildren. Consistent with this interpretation, in a Swiss study of grandparent–grandchild relationships, Coall and colleagues [45] found that earlier reproductive scheduling and having more children and grandchildren were associated with reduced grandparental investment across a range of measures. The present study confirms that grandparental investment, like parental investment in humans [47], is strongly associated with reproductive scheduling.

Theoretical implications

Next, we discuss theoretical implications that our findings have. First, the finding that the biological relationship between grandparents and grandchildren is an independent predictor of high grandparental investment, even in contemporary European nations, is consistent with kin selection theory [44]. The impact of biological relatedness is often seen as incompatible with sociological and economic models of parental and grandparental investment [5,28]. In these models, investment is often assumed to preferentially flow to those grandchildren (and their parents) who are more likely to reciprocate in times of need. If, however, non-biologically related individuals are less likely to reciprocate in the future, which an evolutionary perspective would suggest, our findings may simultaneously support the predictions of the sociological, economic, and evolutionary accounts. Reciprocal altruism, which is most often conceptualized as exchanges between unrelated individuals, is likely to have originally evolved in close kin groups. The psychological traits that maintain a system of reciprocity in humans (e.g., guilt, trust, sympathy, gratitude [48]) are likely to be stronger between close kin and to promote kin as less risky partners with whom to reciprocate [49]. Similarly, just as they are proposed to do in parent-child relationships [14], quality grandparent-grandchild attachment relationships may provide a crucial proximate mechanism whereby grandparents identify and preferentially care for biological grandchildren [26,50]. Indeed, the many non-biological grandparents who *do* invest may do so because of particularly harmonious relationships between family members. It is therefore likely that investment in biological grandchildren improves inclusive fitness and is simultaneously more likely to be reciprocated. Consequently, our findings are not necessarily at odds with economic or sociological accounts of grandparental investment.

Second, there are also challenges to all these theoretical perspectives. If biological relatedness or the expected reciprocation are central, why is it that so many grandparents, both biological and non-biological, do not invest? Obviously, these theories are not designed to explain or predict a lack of investment. Unfortunately, by definition, large-scale databases provide less information on respondents who do not invest, and therefore little is known currently about why grandparents do not invest.

Third, our investigation found no evidence for some predictors of grandparental investment that are commonly found. The most obvious of these is the effect of grandmothers investing more than grandfathers, and maternal grandparents investing more than paternal grandparents [2,26], a finding that has been previously identified in this database when the focus was on biological grandparent–grandchild dyads [25]. In the current analysis, significantly more biological grandparents were grandmothers, which may reflect divorce and remarriage patterns, and investment by grandmothers in more certain kin [51]. These findings raise questions about the boundary conditions of patterns of grandparental investment by sex and lineage.

Limitations

Our investigation has several limitations. Among them, the main one is that the biological relatedness variable focuses on whether the grandparent is related to his/her children (and, by extension, to his/her grandchildren). If a grandparent divorces and re-marries, he/she may then have non-biological children. Similarly, if the grandparent has children via adoption, they will be non-biological. However, we do not have information on the biological relationship between the second (children) and third (grandchildren) generations. That is to say, we cannot take into account divorce or adoption in the parents' generation (G2). This limitation means that our estimate of biological relatedness is overestimated and that larger effects of biological relatedness may be present.

A second limitation is the (relative) scarcity of individual-level information. On the one hand, we were able to draw on extensive information about the grandparents: their tangible investments in the form of informal childcare, their children's employment, family structure, conflicts within the family, and obligations towards the family. On the other hand, more information on other contacts between grandparents and grandchildren, socio-economic resources, and the demands on them from other family members would have improved the analysis [52]. Unfortunately, the SHARE database does not include information on other types of investment, such as financial support, which may reveal different patterns of investment [53]. Also, because we were unable to establish whether grandparents have both biological and non-biological children, we were not able to conduct within-family comparisons. Nonetheless, the fact that we included numerous control variables minimizes the risk that this finding is spurious.

A third limitation is the blunt measure our regions variable provides. Our aim was to adjust for potential regional differences in grandparental investment patterns. There is, however, a multitude of unmeasured cultural factors that impact grandparental investment decisions and may account for further variance in our models. Cross-cultural analyses show that culture-specific differences impact grandparental investment patterns [17]. Future research could use large datasets such as SHARE complemented with diverse measures of cultural differences to examine their impact on investment.

Last but least, let us emphasize that our investigation concerned quantity of investment, not its consequence. We cannot determine whether biological or non-biological grandparental investments are more *beneficial* to grandchildren, and the patterns of available evidence do not permit simple conclusions. Interventions designed to promote interactions between unrelated older people (≥ 60 years) and adolescents—not dissimilar to contact between grandparents and grandchildren—have been shown to have cognitive or health benefits for both generations [54]. However, under some conditions, purportedly biologically related grandparents (but see [17]) can decrease the probability of their grandchildren surviving (e.g., paternal grandmothers; [55,56]). Conversely, in low-resource family environments, grandfathers can fill crucial roles within the family [57]. To reiterate: We found that, independent of a range of likely confounding factors, non-biological grandparents are less likely to invest intensively in their grandchildren—the consequences of these investments, or lack thereof, for grandchildren remain open.

Conclusion

Across human societies, both biologically and non-biologically related individuals contribute to the survival and development of subsequent generations. As fertility rates fall and divorce and remarriage rates rise, the proportion of non-biologically related family members in western families is increasing. Unfortunately for parents and their children, having more grandparents to call upon in theory does not mean more support in practice: Non-biological grandparents are less likely to provide high levels of informal childcare. Data from this multi-national investigation of European societies are thus still consistent with a crucial theoretical underpinning of the modern evolutionary synthesis, namely that biological relatedness is a predictor of investment behavior [44]. Paradoxically, we also found that biological relatedness is associated with an increased risk of providing no grandparental investment at all. Crucially, our study highlights the necessity of a comprehensive framework of grandparental investment including sociological, economic, psychological, and evolutionary measures and concepts.

Competing interests

We have no conflict of interest.

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Supporting information to manuscript 1

This file provides supporting information explaining the data analysis in more detail. First, Table S1 presents descriptive data for the dependent and independent variables and covariates used in the study. Second, we investigate whether grandparents who look after their grandchildren on a daily basis are in fact probably substitute parents—SHARE does not provide this information (Table S2). Third, Table S3 lists true confounders identified to be significantly associated with both biological relatedness and grandparental investment. Fourth, we explore the potential mediation effect of age on health (Table S4). Fifth, Table S5 evaluates the independent effects of fertility rates and geographic regions on grandparental investment. Sixth, Table S6 displays additional details of the main multinomial logistic regressions conducted. Last, we tested the robustness of the initial analysis by re-running the analyses using different methods and altering the measurement of grandparental investment (Tables S7, S8, and S9).

Table S1. Descriptive data for dependent, independent, and covariates used in this study

Variable	Categories	Mean (%[a])	SD[b]	*N*
Grandparents				
Investment	Almost daily childcare	8.3		1904
	Almost weekly childcare	15.1		3466
	Almost monthly childcare	10.8		2475
	Less often childcare	15.5		3551
	Never childcare	50.3		11526
Biological grandparent	Yes	90.2		20710
	No	9.8		2257
Grandparent sex	Female	56.4		12959
	Male	43.6		10008
Grandparent lineage	Maternal	50.8		11663
	Paternal	49.2		11304
Filial expectations		3.8	0.8	15343
Distance to (grand)child		4.7	1.9	22919
Number of children		2.7	0.9	22967
Number of grandchildren		4.0	2.6	22967
Grandparent's age		68.7	9.8	22959
Grandparent's health		3.6	0.9	11261
Conflict with children	High	29.0		4236
	Low	71.0		10376
Conflict about grandchildren's upbringing	High	12.3		1750
	Low	87.7		12423
Savings (in euro)		21766	92220	8828
Grandparent's education		4.4	4.7	20985
Grandparent employed	Yes	31.1		5431
	No	69.9		12623
Grandparent has a partner	Yes	62.7		14402
	No	37.3		8564

Children				
Age of child		36.4	9.9	22773
Education of child		5.7	4.7	21607
Child employed	Yes	78.3		17576
	No	21.7		4859
Child has a partner	Yes	75.3		16254
	No	24.7		5328
Grandchildren				
Age of youngest grandchild		10.0	8.5	13797
Macro-economics				
Fertility rates[c]		1.6	0.22	22967
	Italy	1.32		1946
	Greece	1.33		1938
	Germany	1.34		2268
	Spain	1.34		2099
	Austria	1.41		1713
	Switzerland	1.42		688
	Netherlands	1.71		2218
	Belgium	1.72		3197
	Sweden	1.77		2971
	Denmark	1.80		1613
	France	1.92		2299
Regions	North/central	63.5		14583
	South/central	36.5		8384

[a] percentage is shown for dichotomous variables
[b] standard deviation is absent for dichotomous variables
[c] standard deviation and range are absent for the country-specific fertility rates

Are Participants who Report Almost Daily Grandparental Investment Substitute Parents?

SHARE does not provide information about whether grandparents are primary caretakers for grandchildren. If this were the case for grandparents looking after grandchildren on a daily basis, this level of investment could not be compared with other investment levels, where opportunity costs for grandparents occur. Therefore, we examined whether grandparents reporting almost daily investment actually looked after their grandchildren 24 hours a day. As displayed in Table S2, there is no indication that grandparents investing almost daily are primary caretakers. More than 90% of them reported looking after grandchildren for 10 hours a day or less.

Table S2. Cumulative percentage of hours of grandparental investment for the almost daily level

Hours looked after grandchildren almost daily	Biological grandparent *n* (%)	Non-biological grandparent *n* (%)	Total sample (%)
1	6.0		5.8
2	25.5	21.1	25.3
3	36.9	71.1	38.4
4	50.1	76.3	51.2
5	59.1	84.2	60.2
6	73.0	87.4	73.5
7	76.5		76.9
8	85.5	94.7	85.9
9	87.3		87.6
10	91.7		91.9
11	92.0		92.1
12	94.2		94.2
15	94.5		94.5
16	94.7		94.7
18	95.3		95.3
20	95.9		95.8
23	96.2		96.2
24	100.0	100.0	100.0

Identification of True Confounders

Only covariates showing significant variation in both grandparental characteristics and grandparental investment are considered to be true confounders. Table S3 presents the results of additional tests conducted to identify these true confounders. The *Biological relatedness* column shows results from the initial chi-square (χ^2 for dichotomous variables) and Mann–Whitney U tests (Z values for continuous variables). Additionally, the *Investment* column presents Spearman coefficients (rho), indicating significant variation in investment levels for each covariate. The *True confounder* column shows whether or not a covariate was associated with both biological relatedness and grandparental investment: 17 variables were identified as true confounders and used in our main analysis predicting grandparental investment (Table 2 of our article and Table S6). They were biological relatedness, sex of grandparent, filial expectation, distance to (grand)child, number of children, number of grandchildren, age of grandparent, child, and grandchild, health status of grandparent, conflicts about the upbringing of grandchildren, education of grandparent and child, partner status of grandparent, work status of child, country-specific fertility rates, and regions. The covariate *Lineage* (and therefore sex of child), although not emerging as a true confounder, was also included in the final model. This variable’s lack of statistical association with biological relatedness is easily explained: a child’s sex cannot be expected to be dependent on whether or not the parent is a biological relative. However, there was a strong association with investment, as expected from a theoretical viewpoint. This important covariate was therefore also included in the multinomial logistic regression.

Table S3. List of true confounders associated with both biological relatedness and grandparental investment (chi-square, Mann–Whitney U tests, and Spearman correlations [rho])

Variable	Biological relatedness[a,b]	Grandparental investment (rho)	True confounder
Grandparents			
Investment	127.4***	-	-
Biological grandparent		.04**	Yes
Grandparent sex	122.9***	.02**	Yes
Grandparent lineage	0.06	.02**	No (Yes)
Filial expectations	-10.8***	.07**	Yes
Distance to (grand)child	-13.9***	-.14**	Yes
Number of children	-21.7***	-.02**	Yes
Number of grandchildren	-1.9**	-.10**	Yes
Grandparent's age	-22.5***	-.37**	Yes
Grandparent's health	-3.8***	.12**	Yes
Conflict with children	0.70	.02**	No
Conflict about grandchildren's upbringing	18.9***	.04**	Yes
Savings (in euro)	-0.98	.02*	No
Grandparent's education	-9.2***	.10**	Yes
Grandparent employed	0.38	.00	No
Grandparent has a partner	250.3***	.20**	Yes
Children			
Age of child	-18.8***	-.35**	Yes
Education of child	-5.8***	.11**	Yes
Child employed	41.4***	.05**	Yes
Child has a partner	1.1	-.02**	No
Grandchildren			
Age of youngest grandchild	-4.5***	-.43**	Yes
Macro-economics			
Fertility rates	-20.4***	-.02**	Yes
Regions	602.0***	.02**	Yes

[a] χ^2 values are given for dichotomous variables
[b] Z values are given for continuous variables
* $p < .05$, ** $p < .01$, *** $p < .001$

Potential Mediation Effect of Age on Health

We conducted an additional multinomial logistic regression to investigate whether the effect of grandparental age on grandparental investment was mediated by grandparental health (Table S4). Results show that there was no mediation of age through health. In fact, both variables independently accounted for variance in each of the investment levels relative to *no investment* (reference level).

Table S4. Odds ratios (Exp[B]) and significance levels of multinomial logistic regression testing the potential mediation effect of grandparent's age by health on grandparental investment

	Almost daily childcare		Almost weekly childcare		Almost monthly childcare		Less often childcare	
	Exp(B)	p	Exp(B)	p	Exp(B)	p	Exp(B)	p
Grandparent's age	.92	***	.90	***	.91	***	.92	***
Grandparent's health	.87	**	1.39	***	1.34	***	1.37	***

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

Can Grandparental Investment be Predicted by Fertility Rates or Geographic Regions?

Using the SHARE database, Hank and Buber [36] found a north–south gradient in regular grandparental investment across Europe. They showed that grandparents in the Nordic countries looked after their grandchildren less regularly than did those in central and southern Europe. This difference could be attributable to macro-economic determinants, such as the pattern of childcare provided by the state probably leading to higher fertility rates but less grandparental involvement in the Nordic countries. Table 1 of our article shows that being a non-biological grandparent is associated with higher fertility rates, with living in the north/central region of Europe, and also with less frequent investment. Table S3 shows that higher fertility rates (e.g., in the Nordic countries) are also associated with less frequent grandparental investment. Therefore, fertility rates may reflect underlying structural determinants for each country [3], and both variables should be taken into account. In order to test the effect of fertility rates versus geographic regions, we included both variables in a multinomial logistic regression (Table S5).

Results reveal that both variables independently account for variance in almost all of the investment levels relative to *no investment* (reference level).

From a theoretical viewpoint, fertility rates may reflect macroeconomic structures in a more tangible way than plain geographic regions. However, the independent influence of geographic borders indicates that there may be socio-economical differences strongly shaping grandparental investment. Shedding light on these influences in more detail would go far beyond the scope of this study. However, including both variables in the main analysis (Table 2 of the article, and Table S6 below) can provide some evidence for possible socio-economic influences that warrant further investigation in future studies.

Table S5. Odds ratios (Exp[B]) and significance levels of multinomial logistic regression testing the independent effects of fertility rates and regions of Europe

	Almost daily childcare		Almost weekly childcare		Almost monthly childcare		Less often childcare	
	Exp(B)	p	Exp(B)	p	Exp(B)	p	Exp(B)	p
Fertility rates[c]	.06	***	.73	*	2.55	***	5.68	***
Regions	.85	*	1.75	***	1.72	***	1.37	***

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

Details of the Main Multinomial Logistic Regression

Table S6 provides more details of the multinomial regression for each investment level. The covariates are ordered by the strength of their odds ratio and significance level, making it easier for readers to identify which covariates are most important for which level of investment.

Table S6. Detailed results for each investment level from the multinomial logistic regression investigating grandparental investment

Almost daily investment	Exp(B)	p	95% CI Exp(B)		B	S.E.	Wald
Child employed (yes)	1.95	***	1.36	2.79	0.67	0.18	13.21
Fertility rates	0.13	**	0.03	0.58	-2.02	0.75	7.27
Filial expectations	1.79	***	1.47	2.18	0.58	0.10	33.79
Grandparent has a partner (yes)	1.79	***	1.29	2.49	0.58	0.17	12.16
Regions (north/central)	0.43	**	0.25	0.74	-0.85	0.28	9.32
Grandparent lineage (maternal)	1.54	**	1.16	2.02	0.47	0.14	9.27
Biological grandparent (yes)	1.51	*	0.81	2.82	0.41	0.32	1.66
Distance to (grand)child	0.71	***	0.65	0.77	-0.35	0.04	64.61
Number of children	0.71	**	0.57	0.88	-0.34	0.11	9.39
Grandparent's health	0.83	*	0.71	0.98	-0.18	0.08	4.75
Age of youngest grandchild	0.91	***	0.89	0.94	-0.09	0.02	33.57
Education of child	1.09	**	1.02	1.16	0.08	0.03	6.14
Grandparent's age	0.92	***	0.89	0.95	-0.08	0.02	31.95
Number of grandchildren	1.08	*	1.00	1.16	0.07	0.04	3.68
Age of child	0.93	***	0.90	0.97	-0.07	0.02	11.79
Household identifier	0.97		0.95	1.02	-0.04	0.01	6.22
Grandparent sex (female)	1.24		0.91	1.69	0.21	0.16	1.79
Conflict about grandchildren's upbringing (high)	1.18		0.83	1.68	0.17	0.18	0.85
Grandparent's education	1.01		0.95	1.09	0.01	0.03	0.17

Almost weekly investment							
Biological grandparent (yes)	1.57	*	1.09	2.25	0.45	0.19	5.76
Grandparent has a partner (yes)	1.38	**	1.09	1.75	0.32	0.12	7.07
Filial expectations	1.24	**	1.08	1.41	0.21	0.07	9.56
Distance to (grand)child	0.79	***	0.74	0.84	-0.24	0.03	53.09
Grandparent's health	1.18	**	1.04	1.33	0.16	0.06	6.91
Grandparent's education	1.09	***	1.03	1.15	0.09	0.03	11.93
Age of youngest grandchild	0.92	***	0.90	0.94	-0.08	0.01	45.45
Child employed (yes)	1.08	ns	0.83	1.40	0.07	0.13	0.30
Grandparent's age	0.93	***	0.91	0.95	-0.08	0.01	47.43
Age of child	0.94	***	0.91	0.96	-0.07	0.02	18.86
Grandparent sex (female)	1.22		0.97	1.54	0.20	0.12	2.84
Fertility rates	0.81		0.32	1.64	-0.21	0.42	0.25
Regions (north/central)	1.13		0.80	1.71	0.12	0.18	0.46
Conflict about grandchildren's upbringing (high)	0.86		0.63	1.17	-0.15	0.16	0.92
Grandparent lineage (maternal)	1.06		0.86	1.30	0.06	0.11	0.30
Number of grandchildren	1.04		0.98	1.09	0.04	0.03	1.62
Number of children	0.97		0.83	1.14	-0.03	0.08	0.10
Education of child	1.00		0.95	1.06	0.01	0.03	0.01
Household identifier	0.96		0.95	1.03	-0.02	0.01	2.59
Almost monthly investment							
Fertility rates	4.02	**	1.35	7.90	1.39	0.46	9.03
Regions (north/central)	1.66	*	1.08	2.56	0.51	0.22	5.28
Filial expectations	1.46	***	1.24	1.71	0.38	0.08	21.47
Child employed (yes)	1.37	*	1.00	1.91	0.32	0.17	3.64
Grandparent sex (female)	1.31	*	1.00	1.70	0.27	0.14	3.83
Age of youngest grandchild	0.90	***	0.87	0.92	-0.11	0.02	50.78
Grandparent's education	1.09	**	1.02	1.15	0.08	0.03	7.25
Grandparent's age	0.93	***	0.91	0.96	-0.07	0.01	29.74
Education of child	0.93	*	0.88	1.00	-0.07	0.03	4.08
Age of child	0.97	*	0.93	1.00	-0.04	0.02	3.82
Household identifier	0.99		0.96	1.04	-0.03	0.02	3.77
Grandparent lineage (maternal)	0.83		0.65	1.05	-0.19	0.12	2.39
Grandparent has a partner (yes)	1.14		0.87	1.50	0.13	0.14	.86
Conflict about grandchildren's upbringing (high)	0.87		0.59	1.29	-0.14	0.20	0.46
Number of children	1.11		0.92	1.33	0.10	0.10	1.14
Grandparent's health	1.10		0.96	1.26	0.09	0.07	1.78
Biological grandparent (yes)	0.98		0.68	1.42	-0.02	0.19	0.01
Distance to (grand)child	0.98		0.92	1.06	-0.02	0.04	0.19
Number of grandchildren	1.00		0.94	1.06	0.00	0.03	0.01

Less often investment							
Fertility rates	5.41	***	2.34	12.50	1.61	0.43	15.63
Grandparent sex (female)	1.29	*	1.03	1.62	0.25	0.12	4.80
Grandparent's health	1.23	***	1.10	1.39	0.21	0.06	11.88
Number of children	1.20	*	1.03	1.40	0.18	0.08	5.14
Distance to (grand)child	1.14	***	1.07	1.21	0.13	0.03	17.35
Age of youngest grandchild	0.93	***	0.91	0.95	-0.07	0.01	44.83
Grandparent's age	0.96	***	0.94	0.98	-0.04	0.01	15.53
Age of child	0.97	*	0.94	1.00	-0.03	0.01	4.89
Conflict about grandchildren's upbringing (high)	0.84		0.60	1.17	-0.18	0.17	1.08
Biological grandparent (yes)	1.10		0.79	1.53	0.10	0.17	0.31
Filial expectations	1.09		0.96	1.24	0.09	0.07	1.78
Grandparent lineage (maternal)	1.07		0.87	1.30	0.06	0.10	0.37
Grandparent has a partner (yes)	0.93		0.75	1.17	-0.07	0.12	0.35
Child employed (yes)	1.05		0.80	1.36	0.05	0.14	0.12
Grandparent's education	1.05		0.99	1.10	0.04	0.03	2.99
Regions (north/central)	1.03		0.70	1.50	0.03	0.19	0.02
Education of child	0.97		0.92	1.03	-0.03	0.03	1.48
Number of grandchildren	0.98		0.94	1.04	-0.02	0.03	0.37
Household identifier	1.00		0.95	1.04	-0.02	0.01	1.12

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

Testing the Robustness of the Results

To test the robustness of the initial multinomial logistic regression predicting grandparental investment, we re-ran the analyses using different methods and altering the outcome variable. The covariates included remained the same as in the initial analysis.

First, we ran a binary logistic regression with the outcome variable dichotomized into high (almost daily/weekly) and low investment (almost monthly/less often/never). The results (Table S7) are similar to those produced by the initial multinomial logistic regression. Second, all non-investors—who accounted for 50.3% of the total sample—were excluded, and a multinomial logistic regression (Table S8) and a binary logistic regression (Table S9) were conducted. Again, the results were very similar to the initial analysis, suggesting that these are robust effects.

Table S7. Odds ratios (Exp[B]), significance levels, and confidence intervals of binary logistic regression for entire sample including non-investors (reference category: low investment)

Independent variables	Exp(B)	p	95% CI Exp(B)	
Biological grandparent (yes)	1.50	**	1.11	2.04
Grandparent sex (female)	1.09		0.90	1.32
Grandparent lineage (maternal)	1.22	*	1.03	1.44
Filial expectations	1.26	***	1.13	1.41
Distance to (grand)child	0.74	***	0.70	0.78
Number of children	0.84	**	0.74	0.96
Number of grandchildren	1.06	**	1.01	1.10
Grandparent's age	0.95	***	0.93	0.96
Grandparent's health	1.00		0.91	1.11
Conflict about grandchildren's upbringing (high)	1.03		0.81	1.32
Grandparent's education	1.04		1.00	1.08
Grandparent has a partner (yes)	1.50	***	1.23	1.82
Age of child	0.95	***	0.93	0.98
Education of child	1.05	*	1.01	1.09
Child employed (yes)	1.22		0.98	1.51
Age of youngest grandchild	0.94	***	0.92	0.96
Fertility rates	0.22	***	0.11	0.45
Regions (north/central)	0.77	*	0.57	1.03
Household identifier	0.99		0.95	1.02

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

Table S8. Odds ratios (Exp[B]) and significance levels of a multinomial logistic regression for each grandparental investment level excluding non-investors (reference category: less often)

	Almost daily childcare		Almost weekly childcare		Almost monthly childcare	
Independent variables	Exp(B)	p	Exp(B)	p	Exp(B)	p
Biological grandparent (yes)	1.50	*	1.59	*	0.96	
Grandparent sex (female)	0.94		0.92		0.96	
Grandparent lineage (maternal)	1.32	*	0.98		0.78	
Filial expectations	1.64	***	1.15		1.38	***
Distance to (grand)child	0.61	***	0.68	***	0.87	**
Number of children	0.67	**	0.89		0.95	
Number of grandchildren	1.08	*	1.04		1.00	
Grandparent's age	0.95	**	0.96	**	0.97	*
Grandparent's health	0.64	***	0.94		0.91	
Conflict about grandchildren's upbringing (high)	1.51		1.11		1.06	
Grandparent's education	0.97		1.04		1.04	
Grandparent has a partner (yes)	2.13	***	1.50	**	1.22	
Age of child	0.97		0.97	*	0.99	
Education of child	1.13	**	1.03		0.96	
Child employed (yes)	1.66	*	0.93		1.23	
Age of youngest grandchild	0.97		0.99		0.97	*
Fertility rates	0.03	***	0.15	***	0.81	
Regions (north/central)	0.54	***	1.00		1.44	
Household identifier	0.98		0.95		0.97	

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

Table S9. Odds ratios (Exp[B]), significance levels, and confidence intervals of binary logistic regression excluding non-investors (reference category: low investment)

Independent variables	Exp(B)	p	95% CI Exp(B)	
Biological grandparent (yes)	1.62	*	1.08	2.47
Grandparent sex (female)	1.25	*	1.00	1.57
Grandparent lineage (maternal)	1.88	***	1.53	2.32
Filial expectations	1.29	***	1.12	1.48
Distance to (grand)child	0.63	***	0.59	0.67
Number of children	0.46	***	0.39	0.54
Number of grandchildren	1.09	**	1.03	1.15
Grandparent's age	0.96	***	0.94	0.98
Grandparent's health	0.99		0.87	1.11
Conflict about grandchildren's upbringing (high)	0.89		0.66	1.18
Grandparent's education	1.08	**	1.03	1.13
Grandparent has a partner (yes)	1.70	***	1.34	2.17
Age of child	0.96	*	0.94	0.99
Education of child	0.99		0.95	1.05
Child employed (yes)	1.49	**	1.15	1.93
Age of youngest grandchild	0.93	***	0.91	0.96
Fertility rates	0.53		0.22	1.27
Regions (north/central)	0.76		0.53	1.10
Household identifier	0.98		0.96	1.03

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

Author's comment on manuscript 1

Biological Grandparents Do Invest More:

A Linear Mixed Effects Reanalysis

Sonja Hilbrand[1*], David A. Coall[2,3], Ralph Hertwig[4]

[1] Faculty of Psychology, University of Basel, Basel, Switzerland

[2] School of Medical and Health Sciences, Edith Cowan University, Joondalup, Western Australia

[3] School of Psychiatry and Clinical Neurosciences, University of Western Australia, Crawley, Western Australia

[4] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

* Correspondence concerning this article should be addressed to Sonja Hilbrand (s.hilbrand@unibas.ch)

Summary

In our analysis of grandparental investment [1], we found that biological relatedness predicted more frequent grandparental investment in contemporary Europe. Both multinomial logistic regression and binary logistic regression confirmed the independent role of biological grandparenthood after the adjustment for potential confounding factors. In the multinomial logistic regression analysis, being biologically related to a grandchild was associated with more than a 50% increase in the probability of looking after grandchildren almost daily or weekly [1]. Here we further examined the robustness of the original results. Specifically, we conducted an additional linear mixed effects analysis. This procedure uses both fixed and random effects that correspond to the hierarchy of clustering in nested data [2]. This reanalysis confirmed the predictive role of biological relatedness as an independent predictor of informal grandparental childcare.

Hierarchical data structure

Using the SHARE database [3], we explored grandparents' (generation G1) investment in grandchildren (generation G3) through the grandparent–child (generation G1–generation G2) dyad. The SHARE database allowed us to identify up to four grandparent–child (G1–G2) dyads from the same grandparent. These dyads are inherently dependent within the same grandparent representing the first level of hierarchy. Furthermore, there are multiple responses per grandparent on any other factor explored in the analysis and these responses are also dependent on the family membership the specific grandparent-grandchild dyad was formed from. These interdependencies represent the second level of hierarchy (between-family variance). The third hierarchical level of clustering is represented by geographic nesting of the data that arose from data collection across eleven countries of Europe (between-region variance).

Random effects and model selection

By specifying random effects in our model, we could accommodate the unsystematic or unmeasured variation in the data that may be expected at all three levels of data clustering. Therefore, the results could be generalized to the whole population the data was collected from [see 4].

In order to control for the variance explained by family membership, we defined the variable *household identifier* as a subject random effect. This variable was provided by SHARE and consisted of a personal code for each grandparent. In order to select the best descriptive model, we compared the model fit of different model specifications, using the Bayesian information criterion (BIC). Most models showed a BIC between 3954.23 and 4041.50. We then entered an interaction term, including a random intercept, between level 2 and 3 (between-family and between-region). This allowed us to specify that each family has its own set of parameters for the random effect of *region* [see 5 for statistical details]. Including this interaction term resulted in a BIC of 473.23. According to [2], a reduction in the BIC by 2 points indicates a significant improvement in model fit.

Fixed effects

Including fixed effects in the linear mixed effects analysis accounts for systematic variation in the data [4]. Therefore, fixed effects are treated like predictor and control variables in other statistical procedures, such as logistic regression or ANOVA. In order to maintain consistency, we entered the same predictor and control variables as in our initial analysis (see [1] for detailed description of the variables): *biological* versus *non-biological grandparent*, *grandparent’s sex*, child’s sex (represented by *lineage*), *distance* to (grand)child, *number of children and grandchildren*, grandparental *health* and *age*, *age* of children and grandchildren, grandparents’ and children’s *education*, grandparents’ *partner* status, *work* status of children, and geographic *region* (dichotomised into *north/central* versus *south/central*). The region variable was dichotomised following Hank and Buber’s [6] finding of a north-south gradient in grandparental childcare using the SHARE database.

Unfortunately, two variables from our original analysis were dropped due to the problem of missing data which the mixed-model analysis is sensitive to, namely, *filial expectations* and conflicts with children over the *upbringing of grandchildren*. These two variables were part of a drop off paper-and-pencil questionnaire that grandparents returned themselves by mail; therefore, these variables contained more missing values than other variables. *Fertility rates* were also excluded from the analysis because this variable became redundant when the effect of *regions* was included as both fixed and random effects.

Results

Table 1 reports the results of the linear mixed effects analysis. They confirm that biologically related grandparents invested more frequently in their grandchildren than non-biological grandparents. In this analysis, the main effect of biological relatedness accounted for 0.25% of the explained variance in grandparental investment—a small effect [7]. Nevertheless, after controlling for a myriad of confounding factors, the effect of biological relatedness can still be observed in modern European societies. Based on this additional analysis, we can confirm the hypothesis that biological grandparents provide informal childcare more frequently for their grandchildren than do non-biological grandparents.

Furthermore, the significant main effects for several control variables generally point to the same conclusions as in our original analysis. Maternal grandparents looked after their grandchildren (G3) more often than paternal grandparents did. Larger geographic distance to grandchildren reduced the frequency of informal childcare. Grandparental health did not have a significant influence, but older grandparents were less likely to look after their grandchildren. Grandparents (G1) who had a partner and younger children (G2) and grandchildren (G3) were more likely to provide frequent childcare. Frequent informal child care was given more often in the south/central region of Europe. Educational and work status of the child (G2) did not significantly influence grandparental investment nor did grandparents' educational status. The variance explained by the total model (Pseudo R^2) on the between-level (families and regions) was 38.0% and 0.8% on the within-family level.

Table 1. Results from linear mixed effects analysis investigating grandparental investment

Fixed effects	Estimated B	p	S.E.(B)	95% CI		η_p^2 (%)
Intercept	1.69	***	.12	1.46	1.92	-
Biological grandparent (yes)	.11	**	.04	.02	.18	0.25
Grandparent sex (female)	.11	***	.02	.06	.15	0.64
Grandparent lineage (maternal)	.01	**	.00	.00	.02	0.25
Distance to (grand)child	-.01	***	.00	-.01	.00	1.44
Number of children	-.02		.02	-.05	.02	0.04
Number of grandchildren	-.01		.01	-.01	.01	0.01
Grandparent's age	-.01	***	.00	-.01	-.00	0.64
Grandparent's health	.00		.01	-.01	.03	0.04
Grandparent's education	.01		.01	-.00	.02	0.09
Grandparent has a partner (yes)	.13	***	.02	.09	.18	1.21
Age of child	-.01	***	.00	-.01	-.00	0.81
Education of child	.00		.01	-.00	.01	0.01
Child employed (yes)	.03		.03	-.02	.08	0.04
Age of youngest grandchild	-.01	***	.00	-.02	-.01	1.69
Region (north/central)	-.05	*	.02	-.10	-.01	0.16
Random effects interaction						
Intercept | Region*Household identifier	.15	***	.01	.14	.15	-

* $p < .05$, ** $p < .01$, *** $p < .001$, B = parameter estimates, p = significance levels, S.E.(B) = standard errors, 95% CI = confidence intervals, η_p^2 (%) = partial eta squared indicates effect sizes in percentages

There were also a few differences in the current analysis compared to the original analysis. Of theoretical significance is the finding that grandparental sex became statistically significant in the new analysis, indicating that grandmothers invest more, especially within the maternal line (see *lineage*). In the initial analysis, the number of children significantly decreased investment. This finding is no longer significant but the correlation remained negative. The number of grandchildren was positively associated with grandparental investment in the original analysis. In the current analysis, however, the relationship is no longer significant and it reversed. Similarly, the child's education also became non-significant in the new analysis.

The interaction term specifying the random effects of family membership and regions was significant, confirming that there are unmeasured factors which account for the variance explained by the nested data structure. Including these random effects enabled us to control for unsystematic factors influencing the results of the fixed effects. This allowed us to generalize the fixed effects to the whole study population irrespective of the nested data structure.

The effect sizes for each variable shown in Table 1 explain between 0.01% and 1.69% of the variance in grandparental investment. For example, biological relatedness and maternal lineage each accounted for 0.25% of the variance. Age of the grandchild (1.69%) and geographic distance (1.44%) affected grandparental investment most strongly. The effect of regions amounted to 0.16%. Although these effect sizes are small [7], the multitude of biological, psychological, sociological and economic factors associated with grandparental investment show that analyses of grandparental investment require an interdisciplinary approach.

In conclusion, three separate analyses—binary logistic regression, multinomial logistic regression and the current linear mixed effects analysis—confirm the robust effect of biological relatedness on grandparental investment. In the current linear mixed effects analysis, only a few of the non-biological parameters lost their statistical significance or changed their directionality. Several non-biological factors are significantly associated with grandparental childcare. The current findings and those reported earlier [1] suggest that a complete understanding of grandparental investment in contemporary western populations requires an interdisciplinary framework [also see 8].

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5.2 Appendix B: Manuscript 2

Caregiving Within and Beyond the Family Is Associated with Lower Mortality for the Caregiver: A Prospective Study

Sonja Hilbrand[1,2], David A. Coall[3,4], Denis Gerstorf[5], Ralph Hertwig[2]

[1] Faculty of Psychology, University of Basel, Basel, Switzerland

[2] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

[3] School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

[4] School of Psychiatry and Clinical Neurosciences, University of Western Australia, Crawley, WA, Australia

[5] Department of Psychology, Humboldt University, Berlin, Germany

Corresponding author: Sonja Hilbrand, Faculty of Psychology, University of Basel, Missionsstrasse 60/62, 4055 Basel, Switzerland. Tel.: +41 61 267 04 40, s.hilbrand@unibas.ch

Abstract

Grandparenting has been proposed as an ultimate evolutionary mechanism that has contributed to the increase in human life expectancy (see the grandmother hypothesis). The neural and hormonal system – originally rooted in parenting and thus grandparenting – that is activated in the process of caregiving has been suggested as a potential proximate mechanism that promotes engagement in prosocial behavior towards kin and non-kin alike. Evidence and theory suggest that activating this caregiving system positively impacts health and may reduce the mortality of the helper. Although some studies have found grandparental care to have beneficial effects on grandparents' health outcomes, most studies have focused on the detrimental health consequences of providing custodial care for grandchildren. Little is known about how non-custodial grandparental and other forms of caregiving relate to mortality hazards for the care provider. Using an evolutionary framework, we examined whether caregiving within and beyond the family is related to mortality in older adults. Survival analyses based on data from the longitudinal Berlin Aging Study revealed that mortality hazards for grandparents who provided non-custodial childcare were 37% lower than for grandparents who did not provide childcare and for non-grandparents. These associations held after controlling for physical health, age, socioeconomic status and various characteristics of the children and grandchildren. Furthermore, the effect of caregiving extended to non-grandparents and to childless older adults who helped beyond their families. Potential ultimate and proximate mechanisms underlying these effects are discussed.

Keywords: Grandparental care, grandmother hypothesis, mortality, longevity, human cooperation, demographic transition

Introduction

Although human life expectancy has increased substantially in the 20th century (United Nations, 2013), human longevity is not a new phenomenon (Hawkes, 2004). Prosocial behavior, specifically grandmothering, has been proposed as an ultimate evolutionary mechanism that has contributed to the increase in human lifespan expectancy (Kim, et al., 2014). Prosocial behavior may have originally evolved within the family and subsequently extended to a general caregiving system (Brown et al., 2011). The neural and hormonal system that is activated in the process of caregiving represents a proximate mechanism that may reduce human mortality. Indeed, there is growing evidence that grandparenting is beneficial for grandparental health in contemporary societies. For example, the provision of childcare has been shown to have a positive effect on grandparents' cognitive functioning (Arpino & Bordone, 2014), subjective well-being (Mahne & Huxhold, 2015), and risk of depression (Grundy et al., 2012). Yet grandparental caregiving can also deplete grandparents' material and psychological resources and impair their health. These detrimental effects are most pronounced when grandparents provide custodial childcare (Chen & Liu, 2012; Ross & Aday, 2006). A nonlinear relationship has therefore been proposed between the level of care and grandparental well-being (Coall & Hertwig, 2010): just as no contact with grandchildren can impair grandparental physical and emotional health (Drew & Silverstein, 2007), so can intense levels of caregiving. The extent to which the potential health benefits or harms of grandparental care affect not only the health but, ultimately, the mortality of contemporary grandparents has not been systematically studied within an evolutionary framework. To bridge this gap, the present study takes an evolutionary approach exploring whether caregiving within and beyond the family affects the mortality of older helpers. Note that by caregiving we mean non-custodial grandparental caregiving. By helping and prosocial behavior beyond the family, we mean provision of regular but not extensive care to members of the helper's social network.

1.1. Why grandparental caregiving may be associated with mortality

Life history theory seeks to understand human behavior in specific environments by examining how the timing of distinct life phases and investment patterns (e.g., reproduction, grandparental investment and senescence) has been shaped by evolutionary forces. Within this framework, the grandmother hypothesis proposes that Grandparenting, especially grandmothering, is thus seen as conferring a selective advantage that drives human longevity (Kim et al., 2014). Using a mathematical model, Kim and colleagues simulated how human post-menopausal longevity could have evolved. By providing childcare, post-reproductive women aided the survival and reproduction of their descendants, thus increasing the probability that their genes would be transmitted to future generations. This, in turn, created a selective advantage for helping behavior and cooperation in both elderly women and men (but see Rogers, 1993 and Kachel et al., 2010 for conflicting findings). As post-reproductive women still have functional physiological systems (except fertility), it is hypothesized that grandmothering slowed down somatic aging in humans across multiple generations (Hawkes & Coxworth, 2013). Assuming that caregiving offered a selective advantage in humans' evolutionary past and that contemporary humans carry the genes for helping behavior, to what extent may the act of caregiving contribute proximately to survival today? Does the mortality of grandparents who provide care for their grandchildren differ from that of those who do not? Finally, does helping behavior towards non-kin also promote survival, and – if so, to what extent? This last question is particularly important considering of the growing numbers of childless older adults in industrialized societies.

1.2. What are the mechanisms and effects of caregiving beyond the family?

There is emerging evidence that helping others has beneficial health effects for the helper (Brown & Okun, 2014; Morrow-Howell et al., 2003; Musick et al., 1999; Okun et al., 2013). Benefits of caregiving beyond the family would have important implications for at least two reasons. First, the average total fertility rate (TFR) in Europe, for instance, has dropped from 2.3 children per woman in 1970 to 1.6 in 2013, well below replacement level (Population Reference Bureau, 2015). Decreasing fertility rates and more disability-free years will ultimately lead to rising numbers of older adults who do not have grandchildren to care for, but who are willing and able to allocate their resources to the care of others. Second, with demographic change (e.g., divorce and mobility), more grandparents, especially paternal ones, will not be in regular contact with their grandchildren. Do these developments mean that the evolutionary effects of grandparenting on mortality will not survive into the future? Or do the benefits of grandparental caregiving extend well beyond the limits of the family?

Based on the neural circuitry involved in parenting (see Numan, 2006), it has been proposed that a generalized neural and hormonal caregiving system developed over human evolution (Brown et al., 2011). Prosocial behavior may have extended from parenting and grandparenting beyond the family through this caregiving system. Specifically, seeing another person in need may activate the neural caregiving circuitry, thus enabling prosocial behavior (Brown & Okun, 2014). This caregiving system is thought to be the ultimate foundation of caregiving towards non-kin that – on a proximate level – operates through compassion and empathy. This would also be in line with the suggestion that empathy may have both a phylogenetic and ontogenetic basis in the emotional bond between parent and offspring (Preston & de Waal, 2002) but, when activated, extends beyond the family (Hrdy, 2009). These emotional pathways link helping behavior to regulatory physiological systems, which could be among the proximate mechanisms impacting health and mortality. Prosocial behavior towards non-family members may thus recruit the same neural circuitry as (grand)parenting does (Brown et al., 2011). This circuitry is also suggested to buffer negative consequences from stress-related health declines. For example, general helping within and beyond the family has been found to break the link between stress and mortality (Poulin et al., 2013): stress predicted mortality for non-helpers with a hazard ratio of 1.3, but did not predict mortality for helpers (hazard ratio = .96). Moreover, giving help among older adults has been shown to accelerate helpers' recovery from depressive symptoms after spousal loss (Brown et al., 2008) and to reduce mortality (Brown et al., 2003). Taken together, these findings suggest that a neurobiological substrate of prosocial behavior that affects mortality is likely to be involved in caregiving towards both kin and non-kin (Brown et al., 2011; Porges, 2001; Porges, 2003; Porges & Carter, 2011).

Against this background, we first analyzed whether caregiving grandparents have lower mortality than non-caregiving grandparents and non-grandparents. We turned to older adults who cannot provide grandparental care because they have either no children or no grandchildren. The latter group can nevertheless help their children. In our dataset, this help was measured in terms of instrumental help (e.g., doing housework or fixing things). The former group can provide help within their social network beyond the nuclear family. In our dataset, this help was measured in terms of emotional and instrumental support (e.g., comforting others, doing housework, or fixing things). We thus also examined whether parents who give their children instrumental help have lower mortality than non-helping parents. Finally, we investigate whether childless older adults who provide emotional or instrumental support within their social network have lower mortality than those who do not. A large set of covariates was included in all analyses (see below).

2. Material and methods

2.1. Data

Data were drawn from the longitudinal Berlin Aging Study (Lindenberger et al., 2010). BASE is a multidisciplinary investigation of the physical, cognitive and social characteristics of people aged 70 or older living in the former West-Berlin. The BASE dataset contains extensive information on a range of health and social conditions obtained from the participants (generation

1, G1) as well as information provided by G1 about all of their children (generation 2, G2) and grandchildren (generation 3, G3). The BASE sample was randomly selected from the West-Berlin registration office records. Those who agreed to participate completed interviews and medical tests at their homes, doctors' practices and hospitals. The assessments were repeated at approximately 2-year intervals between 1990 and 2009. Detailed descriptions of the variables and procedures used are available elsewhere (Lindenberger et al., 2010; see also https://www.base-berlin.mpg.de/en).

As is often the case in longitudinal study designs, most cases of missing data were due to participant attrition (mortality or moving away from Berlin). The latest update on mortality in 2009 reported that, of the initial 516 participants, 463 had died (89.7%), 33 were alive (6.4%), and 20 (3.9%) were unaccounted for.

2.2. Measures

2.2.1. Dependent variable

Time to death represents mortality. This variable as was measured prospectively and indicates how many years participants lived following the interview at time 1 [T1] until 2009 (when the last round of interviews occurred). In the SI we report an analysis using age at death as the dependent variable (Table S7), which yielded very similar results.

2.2.2. Independent variables

Frequency of caregiving indicates the frequency of grandparental caregiving in the twelve months prior to T1. Grandparental caregiving is defined as looking after or doing something with the grandchild (G3) without the parents (G2) being present. This variable ranges from 1 (never) to 7 (every day). It was extended to include non-grandparents (who were coded as "never"). Note that there were no cases of grandparental caregiving on a daily basis, in other words, our sample did not include any primary or custodial caregivers. Drawing on the frequency of the caregiving variable and whether or not participants had grandchildren, we categorized participants as *caregiving grandparents* (n = 80), *non-caregiving grandparents* (n = 232), or *non-grandparents* (n = 204). A further variable coded whether participants gave *instrumental help to children* (n = 167) or not (n = 203), which was used to measure helping behavior toward descendents (adult children) in participants without grandchildren. This binary variable included instrumental help such as aid with housework or fixing things twelve months prior to T1. To measure support given by childless participants, a binary variable coded instrumental support (e.g., aid with housework or fixing things) or emotional support (e.g., comforting or cheering up someone) provided to others in their social network three months prior to T1 and categorized childless participants into those who *supported others* (*n* = 366) and those who did not (*n* = 150).

2.2.3. Covariates

We controlled for a set of covariates across all three generations. The covariates have previously been shown either to influence time to death (Aichele et al., 2016; Gerstorf et al., 2013), health and aging (Lindenberger, 2014), or grandparental caregiving (Coall et al., 2014; Coall et al., 2009; Tanskanen & Danielsbacka, 2012), or to vary significantly across caregiving grandparents, non-caregiving grandparents and non-grandparents (Table S2 in the SI). Three covariates did not meet these criteria in our data and thus were not included in the main analysis: *education level of grandparents, education level of grandchildren*, and *sex of children*. To verify the exclusion of these covariates we tested whether including them would significantly alter the outcome of the analyses. As Table S3 in the SI shows, this was not the case.

On the level of participants (G1), the covariates accounted for were as follows: Because health is considered to be a multi-dimensional construct, we included two proxies. First, the extent of *comorbidity* was measured as the number of physician-observed diagnoses (as determined in clinical examinations, supported by additional laboratory analysis of blood and saliva samples) of moderate to severe chronic illnesses (according to the International Classification of Diseases, 9th Revision, ICD-9, see World Health Organization, 1979). Second, to measure *functional health*, we used the Instrumental Activities of Daily Living (IADL) scale (Lawton & Brody, 1969). This scale measures independent living skills such as housework and shopping, with higher IADL scores indicating better health. Further covariates were *age*, *sex*, *relationship status* and *income*. *Age at transition to grandparenthood* was defined with respect to the birth of the first grandchild (this transitional age has been shown to be related to mortality (Christiansen, 2014; Coall et al., 2009). The variable *number of children* also included children who had died. The *number of grandchildren* included all living grandchildren. Finally, a variable coded whether or not participants had received emotional or instrumental *support from others* in their social network. On the level of children (G2), the covariates (averaged over all children), were *age*, *education level*, and *relationship status.* On the level of participants' grandchildren (G3), the covariates were *age of the youngest grandchild* (because grandparenting is typically focused on the youngest), geographic *proximity* and whether or not grandchildren were *biological.* Descriptive data on all measures are presented in Table 1. More details on the computation and coding of these variables are provided in the SI.

Table 1. Descriptive statistics: Mortality, participant groups and covariates at T1 (N = 516)

Participants (G1)	Percentage or mean	Range	n
Time to death (years) after T1	5.51	0–22	463
Frequency of caregiving	1.40	1–6	516
Caregiving grandparents	15.50%	–	80
Non-caregiving grandparents	45.00%	–	232
Non-grandparents	39.50%	–	204
Gave instrumental help to children	34.10%	–	176
Gave support to others	70.90%	–	366
Female	50.00%	–	258
Comorbidity	3.69	0-11	516
Functional health	13.53	0–20	516
Age	84.92	70–103	516
Age at transition to grandparenthood	57.22	31–89	312
Number of children	1.28	0–11	516
Number of grandchildren	1.83	0–22	516
Without partner	70.20%	–	362
Education level	1.56	1–5	516
Income	1.56	1–5	516
Received support from others	87.00%	–	449
Children (G2)			
Age	53.20	23–83	379
Female	42.00%	–	159
Education level	1.98	1-5	379
Without partner	35.50%	–	183
Grandchildren (G3)			
Age	19.41	0–46	312
Proximity	5.28	1–8	312
Education level	1.65	1–5	312
Biological	91.70%	–	286

2.3. Data analysis

In a first step, variables with skewed distributions were logarithmically transformed. Model fitting indicated that linear analytic methods were appropriate for investigating the relationship between grandparental caregiving and time to death (see Table S5 and Figure S1 in the SI). We used general linear models, analyses of variance and planned contrasts to test whether grandparental caregiving was associated with grandparental mortality and whether caregiving grandparents lived longer than non-caregiving grandparents and non-grandparents (see SI). Before conducting the survival analysis (Cox regression), the assumption of proportional hazards was tested and confirmed (i.e., that the effect of helping on mortality was the same at all points, see Table S6 in the SI). Four survival analyses were conducted to analyze the association between providing help and mortality. These determined the probability (hazard ratio, HR) that an event (death) will occur within a specified time interval in a given group (e.g., caregiving grandparents) relative to a reference group (e.g., non-caregiving grandparents). Survival analyses are commonly used procedures examining mortality rates between groups and they account for censored data. That is, these adjust for missing information on mortality (in our sample 10.3% of the cases).

The first two survival analyses compared mortality in caregiving grandparents relative to, first, non-caregiving grandparents and, second, non-grandparents. The next analysis tested whether non-grandparents who gave instrumental help to their children (G2) had lower mortality than those who did not. This analysis was restricted to participants who reported having children, but no grandchildren ($n = 151$). The final survival analysis tested whether childless participants ($n = 153$) who helped others within their social network had lower mortality than those who did not. Although we do not know exactly who received their help, by definition it was not children or grandchildren. All survival analyses included a set of covariates related to health and aging: characteristics on which the groups varied on significantly (Table S1 in the SI) and variables associated with grandparental caregiving or time to death (Table S2 in the SI). After testing for possible interactions (see Tables S12 and S13 in the SI), we included an interaction term of health and age in the survival analyses. To evaluate the magnitude of the effects, we present the standardized hazard ratios (HR) in the result tables (Bratt et al., 2016). Similar to beta coefficients in logistic regression the HRs represent the degree of change in mortality risk per unit change in the predictor. An HR below 1.0 indicates a reduced mortality risk; an HR above 1.0, an increased mortality risk. For dichotomous variables, an HR below 1.0 means that the group of interest (e.g., caregiving grandparents) has a reduced mortality risk relative to the reference group (e.g., non-caregiving grandparents). Greater deviations from 1 indicate greater increases or reductions in the mortality risk. To test the robustness of these results, we estimated missing information using the multiple imputation procedure (IBM SPSS, 2011) and conducted linear regressions (see Tables S9, S10, and S11 in the SI). These regression analyses confirmed the results of the survival analyses. All analyses were conducted using SPSS v.22.0 (IBM Corp. Armonk, NY, USA).

3. Results

Was mortality lower among caregiving grandparents than among non-caregiving grandparents (reference category)? The results summarized in Table 2 suggest that this is indeed the case. After adjustment for covariates, a hazard ratio of .63 indicates that the mortality hazard among caregiving grandparents was 37% lower than among non-caregiving grandparents ($p < .05$). Next, was mortality also lower among caregiving grandparents than among non-grandparents (reference category)? Again, the results summarized in Table 3 suggest that this is the case. After adjustment for covariates, a hazard ratio of .63 ($p < .05$) indicates that caregiving grandparents had lower mortality than non-grandparents. In this model, we also included non-caregiving grandparents to compare all three groups in one analysis. Figure 1 illustrates the survival curves for the three groups, showing that caregiving grandparents' mortality was lower than that of either non-caregiving grandparents or non-grandparents. Figure 1 also shows that 50% of caregiving grandparents died within approximately 10 years of T1. The mortality of non-caregiving and non-grandparents did not differ significantly. In both groups, 50% of participants died within approximately 5 years of T1. Covariates contributing significantly to survival were better functional health, female sex, and younger age of the participants.

Table 2. Survival analysis comparing mortality of caregiving grandparents and non-caregiving grandparents, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Non-caregiving grandparents (ref.)	–	–	–	–
Caregiving grandparents	.63	*	.41	.96
Comorbidity	1.50		.89	1.25
Functional health	.94	*	.88	.99
Female	.56	**	.39	.81
Age	1.04	*	1.01	1.08
Age at transition to grandparenthood	.99		.97	1.02
Number of children	1.08		.93	1.25
Number of grandchildren	.93		.86	1.00
Without partner	1.19		.82	1.74
Income	.96		.85	1.07
Received support from others	.97		.55	1.70
Interaction age × health	1.11		.98	1.50
Children (G2)				
Age	1.03		1.00	1.07
Education level	.83		.38	1.83
Without partner	.91		.66	1.24
Grandchildren (G3)				
Age	.99		.96	1.01
Proximity	1.13		.97	1.27
Biological	1.11		1.01	1.78

* $p < .05$, ** $p < .01$

Table 3. Survival analysis comparing mortality of caregiving grandparents, non-caregiving grandparents and non-grandparents, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Non-grandparents (ref.)	–	–	–	–
Non-caregiving grandparents	.90		.78	1.15
Caregiving grandparents	.63	*	.41	.96
Comorbidity	1.05		.89	1.25
Functional health	.94	*	.90	.99
Female	.55	**	.39	.72
Age	1.04	**	1.00	1.08
Age at transition to grandparenthood	1.00		.97	1.02
Number of children	1.08		.93	1.25
Number of grandchildren	.93		.91	1.05
Without partner	1.19		.86	1.00
Income	.96		.85	1.07
Received support from others	.97		.56	1.71
Interaction age × health	1.01		.96	1.25
Children (G2)				
Age	1.03		.99	1.07
Education level	.93		.38	1.83
Without partner	.91		.66	1.24
Grandchildren (G3)				
Age	.99		.96	1.01
Proximity	1.11		.96	1.25
Biological	1.10		1.01	1.51

* $p < .05$, ** $p < .01$

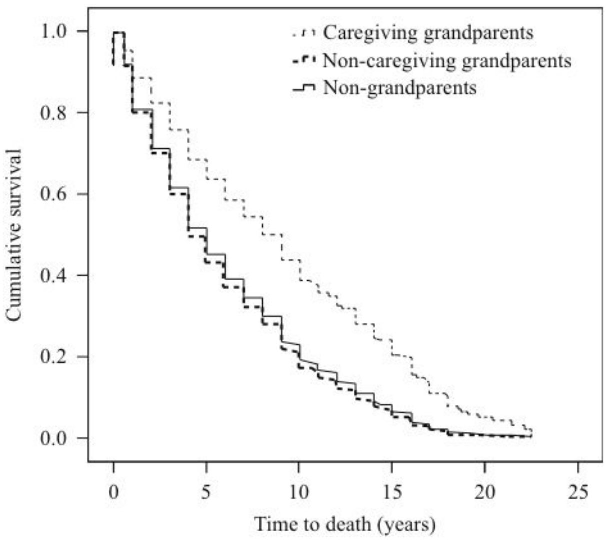

Figure 1. Survival curves as a function of time to death for caregiving grandparents, non-caregiving grandparents, and non-grandparents

We next turn to non-grandparents. Was mortality lower among non-grandparents who gave instrumental help to their adult children than among those who did not? The results summarized in Table 4 suggest that this is the case. After adjustment for covariates, a hazard ratio of .43 ($p < .001$) indicates that parents who gave their children instrumental help had lower mortality than parents who did not. Figure 2 shows, 50% of the helpers died within approximately 10 years of T1, whereas 50% of the non-helpers died within approximately 5 years of after T1. Covariates significantly associated with survival were participants' lower comorbidity, female sex, and younger age.

Table 4. Survival analysis comparing mortality of non-grandparents who gave instrumental help to their adult children and those who did not, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Did not give instrumental help to children (ref.)	–	–	–	–
Gave instrumental help to children	.43	***	.29	.62
Comorbidity	1.09	**	1.01	1.23
Functional health	.97		.92	1.01
Female	.55	***	.46	.79
Age	1.03	***	1.01	1.06
Number of children	.96		.87	1.07
Without partner	1.231		.88	1.72
Income	.96		.87	1.07
Received support from others	.80		.47	1.36
Interaction age × health	1.03		.99	1.32
Children (G2)				
Age	1.04		1.01	1.06
Education level	.72		.33	1.40
Without partner	1.06		.80	1.40

** $p < .01$, *** $p < .001$

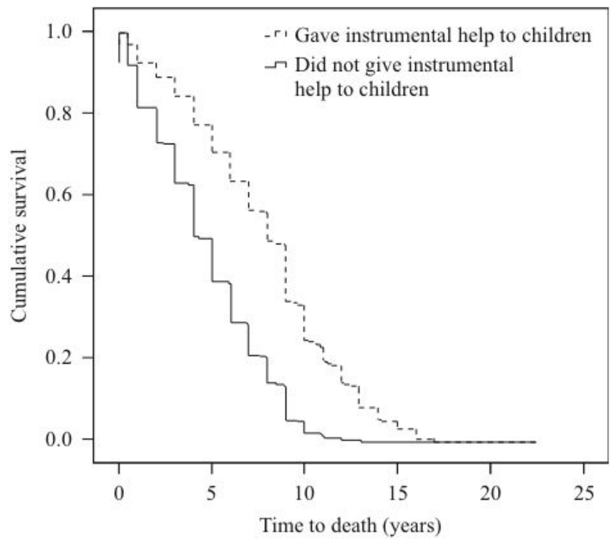

Figure 2. Survival curves as a function of time to death for non-grandparents who gave instrumental helt to their adult children and those who did not

Finally, was mortality lower among childless participants who supported others in their social network than among those who did not? Again, the results presented in Table 5 suggest that this is the case. Relative to non-supporters, supporters had lower mortality (hazard ratio = .40, $p < .001$). Figure 3 shows that 50% of the helpers died within approximately 7 years of T1, whereas 50% of the non-helpers died within approximately 4 years of T1. Covariates significantly associated with survival were lower comorbidity, female sex, and age of the participants.

Table 5. Survival analysis comparing mortality of childless participants who supported others and those who did not, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Did not support others (ref.)	–	–	–	–
Supported others	.40	***	.31	.54
Comorbidity	.97		.87	1.09
Functional health	.93	**	.90	.97
Female	.75	*	.58	.96
Age	1.04	***	1.02	1.06
Without partner	1.06		.81	1.40
Income	.99		.91	1.08
Received support from others	1.25		.87	1.81
Interaction age × health	1.02		.97	1.34

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

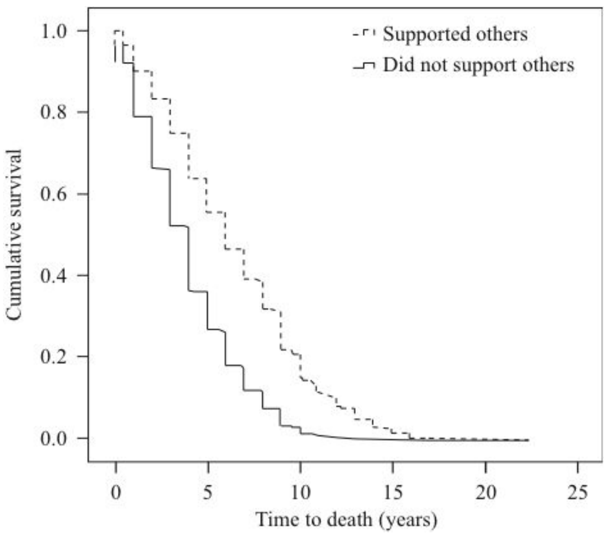

Figure 3. Survival curves as a function of time to death for childless participants who supported others and those who did not

4. Discussion

We consistently found that helping behavior was associated with reduced mortality. All helper groups – grandparents who gave care to their grandchildren; parents who provided instrumental help to adult children; and childless participants who helped others in their social network – had higher survival probabilities than the respective non-helper group. This pattern suggests that there is a link not only between helping and beneficial health effects, but also between helping and mortality, and specifically between grandparental caregiving and mortality. To our knowledge, this is the first longitudinal study to show a link between grandparental caregiving and mortality benefits. It complements previous studies reporting beneficial health effects of grandparental caregiving (Arpino & Bordone, 2014; Grundy et al., 2012). The BASE dataset allowed us to examine mortality outcomes over a period up to 22 years. It also enabled the inclusion of all living grandchildren and thus all caregiving opportunities at the beginning of the study, whereas other studies focused on one grandchild only. Finally, taking advantage of the rich set of covariates, including health and socioeconomic characteristics across all three generations, allowed us to rule out various competing explanations for the survival advantage conferred by caring for others.

4.1. The evolution of helping behavior

The results presented in Figure 2 suggest that providing one's children with instrumental help is associated with decreased mortality. This finding is consistent with the idea that prosocial behavior was originally rooted in parenting (Numan, 2006) and then generalized to grandparenting (see Hawkes & Coxworth, 2013 for a review). Moreover, consistent with previous analyses (e.g., Poulin et al., 2013), we found associations between helping in social networks beyond kin and mortality hazards. It is plausible to assume, in the light of human phylogeny and life history, that the development of prosocial behavior within the family left its imprint on the human body in terms of neural and hormonal circuitries and subsequently laid the foundation for the evolution of cooperation and altruistic behavior towards non-kin. This generalization trajectory is consistent with findings suggesting that caring for non-family members recruits the same neuroanatomical circuits that are engaged in parenting (Swain et al., 2012). We note, however, that such speculation would need to be thoroughly tested in future mechanism-oriented research.

4.2. Is helping a panacea for a longer life?

Our findings contribute to the emerging evidence that supporting others (including non-kin) has beneficial health effects for the helper (Brown & Okun, 2014; Morrow-Howell et al., 2003; Musick et al., 1999; Okun et al., 2013; Shmotkin et al., 2003). However, this association has limits. For example, when grandparents are tasked with full custodial and highly stressful care, the risk to health increases (Bachmann & Chase-Lansdale, 2005; Bowers & Myers, 1999; Chen & Liu, 2012). In other words, whether or not caregiving is beneficial for the helper depends on the level of caregiving. Social strain resulting from extensive caregiving can cancel out potential beneficial effects for the helper (Schulz & Beach, 1999). Our dataset did not include grandparents who were either primary caregivers or helpers who provided extensive amounts of support to others. This may have contributed to the consistency of our findings. Importantly, however, let us emphasize that we merely observed associations between caregiving and mortality hazards. On the basis of these results, we can neither claim causation nor conclude that helping is the panacea for a long life. One reason is that helping may be a necessary but not a sufficient condition for the observed effects to occur. We return to this point below.

4.3. Limitations and future research

The BASE dataset, rich as it is, has limitations. Specifically, it does not include information about participants' motives for helping. Beneficial effects of prosocial behavior on health and mortality have previously been found only when volunteering is other-oriented but not reciprocity-oriented (Konrath et al, 2012). From an evolutionary perspective, it is plausible that other-orientation evolved within the family. The helpers' reward in terms of higher inclusive fitness meant that any expected direct reward was secondary. It follows that the engine behind helping behavior is not primarily reciprocity based (see Kurzban et al., 2015 for a review of altruistic behavior in humans). Indeed, results from health psychology suggest that an expectation of reciprocal reward in the future overrides the positive effects of helping, and that frustrated expectations may even lead to depression for the helper (Keller, 2002). Because we know nothing about our participants' motives, we could not explore their impact further.

The BASE dataset permitted us to include many covariates in the analyses. However, others are also conceivable. For example, we could not control for parents' (G2) work status. Parents who work may need more support with childrearing. Obvious need may boost grandparents' willingness to help, which may in turn impact the relationship between caregiving and mortality. Importantly, we were able to establish that the association between helping and mortality was not due to better health at baseline. In addition, we found that lower mortality in caregiving grandparents was not attributable to the younger age of their grandchildren, which increases the likelihood of caregiving (see Tables S1 and S8 in the SI). Female sex was among the covariates significantly contributing to lower mortality, but we did not find a significant interaction between the helper's sex and caregiving in the prediction of mortality (see SI, Tables S13). In other words, the argument that women tend to be more heavily involved in prosocial behavior than men does not explain the effect of caregiving on mortality. However, we could not examine to what extent associations were mediated by, for example, a less pronounced decline in cognitive (Arpino & Bordone, 2014) or physical health, improved stress response (Poulin et al., 2013), or more social resources available to the helper (Tun et al., 2013). The inclusion of variables that permit researchers to reveal the causal mechanisms underlying the relationship between helping and decreased mortality within and beyond the family will be essential in future longitudinal studies.

Competing interests

We have no conflict of interest.

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Supporting information to manuscript 2

In this document, we explain our analyses in more detail. First, we provide details on the computation and coding of the measures. Second, we present group differences in the characteristics of caregiving grandparents, non-caregiving grandparents, and non-grandparents (Table S1). Third, we report results of analyses identifying covariates to be included in the main analysis (Table S2) and an additional survival analysis (Table S3) in which all potential confounders were included. Fourth, we discuss sample selectivity of the BASE sample and, in addition, compare characteristics of participants who were still alive in 2009 with those who had died (Table S4). Fifth, we present the statistical procedures conducted prior to the main analyses. These procedures examined whether grandparental caregiving was associated with grandparental mortality and whether caregiving grandparents lived longer than non-caregiving grandparents and non-grandparents. Prior procedures also included testing for a possible quadratic relationship between grandparenting and time to death. To this end, we specified a regression model estimating a linear relationship and compared it with a fitted quadratic regression model (Figure. S1, Table S5). Before conducting the main survival analyses, the proportional hazards assumption was tested (Table S6). Sixth, we present an additional survival analysis using age at death rather than time to death as the dependent variable (Table S7). Seventh, we present an additional survival analysis using a sample restricted to grandchildren younger than 17 years (Table S8). Eighth, we estimated missing data and conducted linear regression analyses to further test the robustness of the survival analyses (Tables S9, S10, and S11). Finally, we report analyses testing for possible interactions between health and age (Table S12) and caregiving and participants' sex (Table S13).

Details on computation and coding of measures

In BASE, data on children and grandchildren are presented in person-point format (long format), meaning that each participant occurs as often in the dataset as she or he has children and grandchildren, respectively. Participants without children appear only once in the dataset. In order to have each participant represented equally in the sample, we aggregated the data of those with multiple entries. In the following, we provide additional information on some of the variables used in our analyses and define how the data was aggregated for variables affected by the long format (if not stated in the main text).

Independent variables: *Frequency of caregiving* was measured by the question "How often have you looked after [name of grandchild] in the past year or done something with him/her without the parents being present?" This question was asked for each grandchild. Answers were recoded into 7 = "every day," 6 = "several times a week," 5 = "once a week," 4 =

"once a month," 3 = "several times a year," 2 = "less often," 1 = "never" (including non-grandparents). For those participants who had several grandchildren the frequency of caregiving was averaged across all grandparent–grandchild dyads. By definition, non-grandparents cannot care for biological grandchildren. Participants (G1) with grandchildren (G3) to whom they were not biologically related were still considered as grandparents with the opportunity to care for (non-biological) grandchildren. These participants were coded as 2 = *caregiving grandparents* if they reported any caregiving and 1 = *non-caregiving grandparents* if they did not. The variable indicating whether or not participants gave *instrumental help to children* was aggregated over all children. The variable indicating whether or not participants gave emotional or instrumental *support to others* in their social network was not affected by the long format and no aggregation was necessary.

Covariates: As a proxy of *functional health*, we used the Instrumental Activities of Daily Living (IADL) scale (Lawton & Brody, 1969). The IADL scale is widely used in both clinical practice and research, although its reliability and validity have been questioned (Myers, 1992). It is especially recommended for observing individual decline over time (Graf, 2013). The *number of grandchildren* was calculated by summing up all grandparent–grandchild dyads for each grandparent. *Participants' sex* was coded as 1 (male) or 2 (female). *Children's sex* was aggregated across all dyads and then split into mostly or all male (0) and mostly or all female (1). *Relationship status* of participants and their children were recoded into 1 = with partner, 2 = without partner (including single, widowed, and divorced status). When there were several children, information on their relationship status was aggregated across all dyads and then split into most or all children have a partner (0) and most or all children have no partner (1). *Education levels* were available for participants, children, and grandchildren (averaged over all children and grandchildren) and ranged from 1 = low to 5 = high. The variable *income* represents participants' monthly net income per capita in deutsche mark (DM), weighted by the number of household members, and was grouped into five categories: 1 (<1000), 2 (1000–1399), 3 (1400–1799), 4 (1800–2199), and 5 (> 2200). Geographic *proximity* to grandchildren was recoded into 1 = same household, 2 = same house/building, 3 = neighborhood, 4 = same district, 5 = different district, 6 = different province, 7 = different European country, and 8 = different continent. This variable was averaged across all grandparent–grandchild dyads. Each grandparent–grandchild relationship was coded as *biological versus non-biological* on the basis of a question asked for each child and grandchild: "Is [name of child/name of grandchild] a biological child?" Answers were aggregated over all dyads and recoded as most or all non-biological grandchildren (0) and most or all biological grandchildren (1).

Group differences in the characteristics of caregiving grandparents, non-caregiving grandparents, and non-grandparents

Group differences in characteristics potentially influencing mortality in caregiving grandparents, non-caregiving, and non-grandparents are summarized in Table S1. In terms of functional health, caregiving grandparents were healthier than their counterparts. In addition, they were significantly younger than the other two groups. However, they were significantly older than non-caregiving grandparents at the transition to grandparenthood. Non-grandparents had the fewest children, followed by non-caregiving and then caregiving grandparents. By the same token, caregiving grandparents had significantly more grandchildren than non-caregiving grandparents. In non-grandparents, the percentage of females was significantly higher than in non-caregiving grandparents and caregiving grandparents. The proportion of participants without a partner was significantly higher in non-grandparents and non-caregiving grandparents than in caregiving grandparents. The proportion of participants who supported others in their social network was highest in caregiving grandparents, followed by non-grandparents and then non-caregiving grandparents. Finally, non-caregiving grandparents received the most support from others, followed by caregiving grandparents, and then non-grandparents. There were only three variables on which the three groups did not differ: comorbidity, education level, and income.

Comparing the groups in terms of their children's (G2) characteristics revealed that non-grandparents and non-caregiving grandparents had significantly older children than did caregiving grandparents. The children of non-grandparents had a significantly higher level of education and were more likely to be single than the other two groups. The proportion of female children across the three groups did not vary; thus, there was no difference in terms of lineage (maternal versus paternal grandparents).

Comparing the two grandparental groups in terms of their grandchildren's (G3) characteristics revealed that grandchildren of non-caregiving grandparents were significantly older than the grandchildren of caregiving grandparents. Grandchildren's geographic proximity, education level, and biological relatedness did not differ between the two groups.

Table S1. Differences in characteristics among caregiving grandparents, non-caregiving grandparents, and non-grandparents (N = 516)

	Caregiving grandparents (n = 80)				Non-caregiving grandparents (n = 232)				Non-grandparents (n = 204)			
Participants (G1)	Percentage or mean	Range	SD	n	Percentage or mean	Range	SD	n	Percentage or mean	Range	SD	n
Time to death (years) after T1***	10.60	3–22	3.93	80	5.59	0–20	5.20	232	5.99	0–22	4.89	204
Comorbidity	3.12	0–8	2.12	80	3.89	0–11	2.36	232	3.68	0–11	2.17	204
Functional health***	17.56	5–20	4.77	80	12.87	0–20	7.12	232	12.68	0–20	7.24	204
Age***	77.47	70–95	6.33	80	86.04	70–102	8.05	232	86.56	70–103	8.71	204
Transition to grandparenthood***	60.40	40–89	9.93	80	56.12	31–78	7.59	232	–	–	–	–
Female***	50.10%	–	–	48	49.60%	–	–	115	59.80%	–	–	122
Number of children***	2.43	1–11	1.72	80	1.75	0–7	1.09	232	.30	0–3	.54	204
Number of grandchildren***	3.62	1–22	3.42	80	2.80	1–20	2.8	232	–	–	–	–
Without partner***	40.00%	–	–	32	72.40%	–	–	168	79.40%	–	–	162
Education level	1.73	1–5	1.10	80	1.52	1–5	.93	232	1.53	1–5	.92	204
Income	3.53	1–5	1.33	80	3.49	1–5	1.26	231	3.45	1–5	1.25	204
Supported others***	73.80%	–	–	59	65.90%	–	–	153	67.20%	–	–	137
Received support from others***	88.50%	–	–	70	93.50%	–	–	217	79.40%	–	–	162
Children (G2)												
Age***	43.94	27–62	6.64	80	56.00	31–83	9.01	232	54.55	23–74	9.83	67
Female	38.80%	–	–	31	43.50%	–	–	101	40.3%	–	–	27
Education level*	3.38	1–5	.15	80	3.27	1–5	.16	232	4.05	2–5	.36	67
Without partner**	38.80%	–	–	31	45.30%	–	–	105	70.10%	–	–	47
Grandchildren (G3)												
Age***	7.81	0–16	5.19	80	23.41	0–46	9.26	232	–	–	–	–
Proximity	5.16	3–8	.93	80	5.32	1–8	1.12	232	–	–	–	–
Education level	3.54	1–5	.75	80	3.52	1–5	.35	232	–	–	–	–
Biological	92.50%	–	–	74	91.40%	–	–	212	–	–	–	–

Results of ANOVAs and Chi-squared tests significant at * $p < .05$, ** $p < .01$, *** $p < .001$

Identification of covariates

Only if potential confounders were associated with either the independent variable (frequency of caregiving) or the dependent variable (time to death), or if participant groups differed significantly in potential confounders, did we include them as covariates in the main analysis (see Table S2). Education level of participants and grandchildren as well as sex of children did not meet the criteria to be included as covariates. To verify the exclusion of the three covariates, we tested whether including them would significantly alter the outcome of the main analysis (Table 2), which was not the case: The results in Table S3 are very similar to those emerging from the main analysis.

Table S2. Identification of covariates for the main analysis

Participants (G1)	Frequency of caregiving[a,b]	Time to death[a,b]	Caregiving grandparents, non-caregiving grandparents, non-grandparents[c,d]	Covariate
Comorbidity	.29***	.51***	1.31	yes
Functional health	.21***	.48***	14.01***	yes
Age	−.29**	−.34***	36.99***	yes
Age at transition to grandparenthood	.34***	−.12	15.63***	yes
Number of children	.46***	.11*	163.36***	yes
Number of grandchildren	.39***	.08	147.61***	yes
Sex	4.39***	−.44	32.49***	yes
Without partner	5.76***	.97	39.00***	yes
Education level	.08	.04	1.12	no
Income	.03	.15*	.27	yes
Received help from others	1.27	1.38	18.33***	yes
Children (G2)				
Age	−.40***	−.21***	53.92***	yes
Sex	.05	−.03	.76	no
Education level	.07	−.07	3.30*	yes
Without partner	.15*	.05	11.09**	yes
Grandchildren (G3)				
Age	−.47***	−.04	201.84***	yes
Proximity	−.14**	−.13	1.52	yes
Education level	−.04	.03	1.63	no
Biological	.02	−.37*	.09	yes

[a] r values are given for continuous variables (Pearson correlation)
[b] t values are given for nominal variables (t-test)
[c] F values are given for continuous variables (ANOVA)
[d] χ^2 values are given for nominal variables (Chi-squared test)
* p < .05., ** p < .01., *** p < .001

Table S3. Survival analysis comparing mortality of caregiving grandparents and non-caregiving grandparents, adjusted for all potential covariates

Participants (G1)	HR	p	95% CI of HR	
Non-grandparents (ref.)	–	–	–	–
Caregiving grandparents	.63	**	.45	.91
Comorbidity	1.08		.98	1.34
Functional health	.91	**	.90	.97
Female	.50	***	.35	.72
Age	1.10	***	1.03	1.15
Age at transition to grandparenthood	1.01		.97	1.04
Number of children	1.02		.90	1.15
Number of grandchildren	.97		.90	1.03
Without partner	1.09		.86	1.53
Income	.95		.85	1.08
Received support from others	.97		.61	1.52
Interaction age × health	1.01		.92	1.08
Education level	1.05		.93	1.30
Children (G2)				
Age	1.02		.99	1.05
Education level	.78		.35	.91
Without partner	1.11		.85	1.47
Female	.78		.58	.96
Grandchildren (G3)				
Age	.98		.96	1.04
Proximity	1.03		.92	1.17
Biological	1.35		.16	2.69
Education level	.98		.77	1.32

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

Sample selectivity

As was to be expected, the sample that completed the full BASE protocol was positively selected. For example, participants who completed the full set of interviews and medical examinations showed lower mortality rates than those who did not. However, selectivity analyses have shown that mean variations in the analyzed sections (e.g. sociodemographics, intelligence, health) were always below one standard deviation. Thus, there is no indication for strong systematic patterns of variation between the participants who completed the full protocol and those who did not. Hence, the sample can be considered to be representative (for more details on selectivity analyses, see Lindenberger et al., 2010).

We explored sample selectivity in more detail by comparing participants who were still alive in 2009 with those who had died (Table S4). We conducted independent-samples t-tests for scaled variables, Mann–Whitney U tests for ordinal data, and Chi-squared tests for nominal variables. At T1, participants who were still alive in 2009 were significantly more often caregiving grandparents than non-caregiving grandparents, had fewer comorbidities and better functional health, were younger, more often gave instrumental help to their children and support to others in their social network, less often received support from others, had a higher income, were more often female, and had younger children and grandchildren. The children of these participants were more often female and without a partner.

Table S4. Sample selectivity: Comparison of living and deceased participants in 2009 (N = 496)

	Living participants (n = 33)				Deceased participants (n = 463)			
Participants (G1)	Percentage or mean	Range	SD	n	Percentage or mean	Range	SD	n
Caregiving grandparents**	30.30%	–	–	14	13.10%	–	–	66
Non-caregiving grandparents**	27.30%	–	–	12	46.40%	–	–	220
Non-grandparents	42.40%	–	–	14	39.70%	–	–	190
Comorbidities**	2.00	0–6	1.50	33	3.82	0–11	2.23	463
Functional health***	19.39	10–20	2.40	33	12.98	0–20	7.14	463
Age***	75.21	70–84	4.21	33	85.88	70–103	8.36	463
Gave instrumental help to children*	29.20%	–	–	28	18.10%	–	–	148
Supported others**	90.90%	–	–	28	66.70%	–	–	328
Received support from others*	72.70%	–	–	28	88.10%	–	–	419
Income*	3.96	1–5	1.24	33	3.49	1–5	1.34	463
Female*	63.60%	–	–	22	49.00%	–	–	236
Age at transition to grandparenthood	56.42	31–79	9.98	33	57.19	39–89	8.57	436
Number of children	1.50	0–7	1.46	33	1.25	0–11	1.32	463
Number of grandchildren	1.58	0–10	2.33	33	1.81	0–22	2.48	463
Without partner	66.70%	–	–	23	70.80%	–	–	339
Education level	1.45	1–4	.71	33	1.51	1–5	.81	463
Children (G2)								
Age***	46.40	33–71	7.44	33	54.05	13–83	9.92	463
Female*	67.00%	–	–	20	29.2%	–	–	105
Without partner*	67.20%	–	–	21	34.20%	–	–	109
Education level	3.79	2–5	1.00	33	3.38	1–5	1.43	463
Grandchildren (G3)								
Age**	13.47	0–38	10.25	33	20.22	0–46	11.01	463
Proximity	5.29	2–8	1.20	33	5.26	1–8	1.09	463
Education level	3.46	1–5	4.08	33	3.50	1–5	2.61	463
Biological	99.20%	–	–	26	98.50%	–	–	261

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

Statistical procedures conducted before the main analysis

Before performing the main survival analysis (Cox regressions), we took several steps to investigate whether grandparental caregiving was associated with grandparental mortality and whether caregiving grandparents lived longer than non-caregiving grandparents and non-grandparents.

Results of a general linear model showed that grandparental caregiving increased grandparental survival by 5.27 years (95% CI = .3.72–6.63, $p < .000$). The effect was robust (B = 2.67 years, 95% CI = 1.28–3.51, $p = .001$) after adjustment for the following covariates at T1: giving and receiving support to/from others in the social network, comorbidity and functional health, age of participants, children, and grandchildren, age at transition to grandparenthood, number of children and grandchildren, sex of participants and children, income of participants, relationship status of participants and children, education level of participants, children, and grandchildren, geographic proximity to grandchildren, biological relatedness to grandchildren.

An analysis of variance (ANOVA) revealed that caregiving grandparents (M = 10.61 years, SD = 3.93) lived significantly longer than non-caregiving grandparents (M = 5.62 years, SD = 5.21) and non-grandparents (M = 5.90, SD = 4.89), $F(2, 513) = 33.04$, $p < .000$. Planned contrasts revealed that caregiving grandparents differed significantly from the other groups in terms of mortality. Non-caregiving grandparents and non-grandparents did not differ significantly.

Testing for a possible quadratic association between grandparenting and mortality

In order to examine the nature of the relationship between grandparental caregiving and time to death we compared a linear regression model with a quadratic regression model. Visual inspection of the fitted curve (figure S1) of the quadratic model may suggest that a quadratic function may fit the observed data better than a linear one. This would mean that time to death increases with increases in levels of caregiving ($B1 = 6.81$) until a certain point is reached; from this point on, caregiving starts to negatively impact survival ($B2 = -2.11$) (Table S5). However, there was no significant increase in overall model fit: R^2 increased slightly from 6.20% to 6.40% when the quadratic function was added to the linear model and only the linear model remained significant. This means that the assumption of a linear relationship between grandparental caregiving and mortality is adequate and that it is appropriate to apply linear statistical procedures to the data.

From a theoretical point of view, it is likely that intense levels of care-giving would decrease time to death (Chen & Liu, 2012; Ross & Aday, 2006). In our sample, we had no cases of daily caregiving. This may be the reason why the quadratic function did not provide a significant improvement in fit over the linear model.

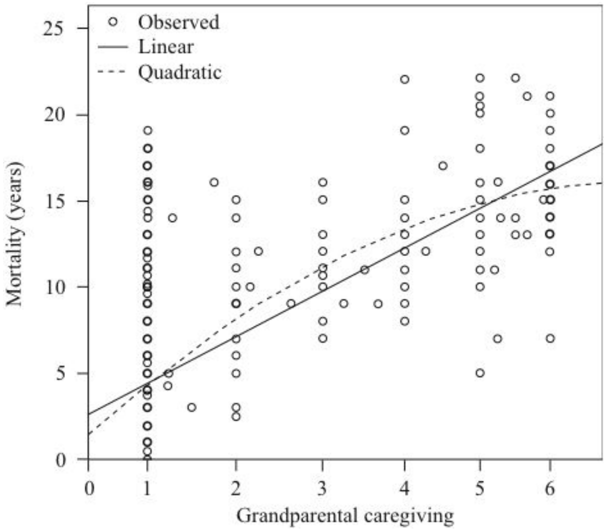

Figure S1. Model fit of linear and quadratic relationships between grandparental caregiving and time to death

Table S5. Model comparison with linear and quadratic relationships assumed between grandparental care and time to death

Equation	B1	B2	p	F	df1	df2	R^2
Linear	4.27		.001	31.59	1	459	.062
Quadratic	6.81	–2.11	.188	16.69	2	458	.064

Testing the proportional hazards assumption

Survival analyses are based on the assumption that the effect of helping is the same at every point in time until the event (death) occurs. To test this assumption we proceeded in several steps (see Hosmer et al., 2008), including calculating survival time rankings and Pearson correlations between these rankings and the partial residuals (Schoenfeld) of the three independent variables and covariates. Results summarized in Table S6 show that survival time rankings did not significantly correlate with the three independent variables (grandparental caregiving, instrumental help given to children, or support given to others in the social network). The correlations between survival time rankings and the covariates also did not reach significance (but are not shown in Table S6, because the three independent variables are the most relevant ones). These results indicate that the proportional hazards assumption is not violated and applying survival analyses is appropriate.

Table S6. Pearson correlations between survival time ranks and partial residuals (Schoenfeld) of the three tested independent variables

	Survival time ranking
Survival time ranking	r = 1
Partial residual for grandparental caregiving	r = .04
Partial residual instrumental help given to children	r = .05
Partial residual for supporting others in the social network	r = .06

Additional survival analysis with age at death as the dependent variable

To test the robustness of the survival analysis conducted (Cox regression), we conducted the same regression with age at death rather than time to death as the dependent variable. Results (see Table S7) were very similar to those presented in the main analysis (see Table 3), suggesting that the findings were robust. Mortality was lower in caregiving grandparents than in non-caregiving grandparents and non-grandparents (hazard ratio = .67, $p < .05$). In the latter two groups mortality did not differ significantly. Other significant factors associated with survival were female sex, better functional health, female sex and younger age of participants.

Table S7. Survival analysis comparing mortality of caregiving grandparents, non-caregiving grandparents, and non-grandparents, using age at death as the dependent variable, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Non-grandparents (ref.)	–	–	–	–
Non-caregiving grandparents	.96		.79	1.18
Caregiving grandparents	.67	*	.51	.98
Comorbidity	1.03		.92	1.17
Functional health	.90	***	.89	.98
Female	.53	***	.35	.72
Age	.81	***	.75	.84
Age at transition to grandparenthood	1.01		.98	1.04
Number of children	1.05		.93	1.22
Number of grandchildren	.97		.91	1.05
Without partner	1.15		.83	1.54
Income	.96		.85	1.07
Received support from others	1.06		.74	1.83
Interaction age × health	1.02		.94	1.35
Children (G2)				
Age	1.01		.97	1.05
Education level	.77		.34	1.51
Without partner	1.14		.83	1.50
Grandchildren (G3)				
Age	.98		.97	1.03
Proximity	1.01		.91	1.10
Biological	1.37		.94	1.51

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

Additional survival analysis restricted to grandchildren younger than 17 years

The grandchildren of caregiving grandparents were significantly younger than those of non-caregiving grandparents (see Table S1). We conducted an additional survival analysis to test whether our finding of lower mortality in caregiving grandparents was due to the increased likelihood of grandparental caregiving in the former group. Using the oldest grandchild of caregiving grandparents as an upper limit, we restricted the sample to grandchildren younger than 17 years. The results (see Table S8) confirm those reported in the main analysis (see Table 2), suggesting that the association between caregiving and longevity was robust to grandchild age. Mortality was lower in caregiving grandparents than in non-caregiving grandparents (hazard ratio = .62, p < .05). Other significant factors associated with survival were age of participants and children, and children without a partner.

Table S8. Survival analysis comparing mortality of caregiving grandparents and non-caregiving grandparents, using a sample restricted to young grandchildren, adjusted for covariates

Participants (G1)	HR	p	95% CI of HR	
Non-caregiving grandparents (ref.)	–	–	–	–
Caregiving grandparents	.62	*	.41	1.03
Age	1.09	*	1.04	1.19
Comorbidity	1.12		.83	1.75
Functional health	1.01		.85	1.12
Age at transition to grandparenthood	1.02		.98	1.07
Female	.69		.42	1.19
Number of children	.88		.75	1.12
Number of grandchildren	1.15		.97	1.26
Without partner	.86		.55	1.39
Income	.89		.75	1.08
Received support from others	.82		.43	1.61
Interaction age × health	1.03		.96	1.35
Children (G2)				
Age	1.03	*	.91	1.05
Without partner	1.82	*	1.06	2.19
Education level	.55		.22	1.74
Grandchildren (G3)				
Age	.96		.91	1.03
Proximity	.98		.76	1.27
Biological	1.65		.73	1.72

* $p < .05$

Linear regression analyses with estimated missing information

We further tested the robustness of the conducted survival analyses by estimating linear regression models. In order to avoid selection biases in favour of younger and healthier individuals, missing information was estimated using multiple imputation (for details, see IBM SPSS Missing Values 20, 2011). This method estimates missing values on the basis of participants' observed data and adds random noise to produce a statistically reasonable degree of variability. SPSS automatically creates a specified number of datasets with complete information on missing data. Each subset varies in terms of the added random noise. To reduce bias in the estimates, we included the outcome variable, all predictors, and covariates in this procedure (for more details, see Spratt et al., 2010). According to Spratt et al. (2010), estimating missing data of the outcome variable is preferable to loosing valuable information due to exclusion of cases with missing data. This procedure resulted in five data subsets with complete information on mortality, predictors, and covariates. The last survivor was estimated to have died in 2015.

The linear regression analyses were run independently for each data subset and results were aggregated, taking variance within each subset and between the subsets into account. The outcome variable was *age at death*. The covariates included in the regression models were the same as in the main survival analyses. In order to facilitate interpretation of the linear regression model, the variable coding grandparents was recoded into 0 = non-grandparents, 1 = non-caregiving grandparents, and 2 = caregiving grandparents. Results presented in Tables S9, S10, and S11 confirmed those of the survival analyses reported in the main article: Grandparental caregiving, instrumental help given to children, and supporting others in the social network significantly predicted age at death. The associations were positive, that is, engagement in helping behavior was predictive of death at an older age.

Table S9. Linear regression predicting age at death for caregiving grandparents, adjusted for covariates (n = 516)

Participants (G1)	B	p	95% CI of B		η_p^2 (%)
Intercept	23.11	***			7.00
Caregiving grandparents	2.46	***	1.17	3.75	4.60
Comorbidity	-.18		-.64	.26	.20
Functional health	.23	**	.08	.38	2.90
Female	2.37	**	1.28	3.45	5.90
Age	.76	***	.63	.89	30.00
Age at transition to grandparenthood	.01		-.08	.10	.00
Number of children	-.21		-.69	.27	.20
Number of grandchildren	.15		-.11	.42	.40
Without partner	-.43		-1.55	.68	.20
Income	.17		-.18	.53	.30
Received support from others	-.35		-1.98	1.28	.10
Interaction age × health	.01		.00	.08	.10
Children (G2)					
Age	-.01		-.12	.09	.00
Education level	1.23		-1.40	3.86	.30
Without partner	-.17		-1.12	.78	.00
Grandchildren (G3)					
Age	.04		-.05	.12	.20
Proximity	-.16		-.57	.24	.20
Biological	-1.31		-2.88	.26	.90

* $p < .05$, ** $p < .01$, *** $p < .001$
B = unstandardized beta coefficient, η_p^2 = partial eta squared

Table S10. Linear regression predicting age at death for helping parents, adjusted for covariates (n = 151)

Participants (G1)	B	p	95% CI of B		η_p^2 (%)
Intercept	17.18	***	9.09	25.28	5.70
Gave instrumental help to children	4.79	***	3.99	5.59	3.20
Comorbidity	-.31	*	-.69	.06	1.80
Functional health	.11	***	-.01	.24	6.00
Female	1.44	**	.52	2.34	3.10
Age	.81	***	.70	.91	43.50
Age at transition to grandparenthood	-.01		-.07	.05	.00
Number of children	-.10		-.51	.29	.00
Number of grandchildren	.11		-.07	.31	.60
Without partner	-.34		-1.28	.59	.20
Income	.22		-.07	.53	.70
Received support from others	-.15		-.15	1.22	.00
Interaction age × health	.00		-.20	.05	.10
Children (G2)					
Age	-.03		-.11	.05	.20
Education level	1.38		-.82	3.59	.50
Without partner	-.62		-1.42	.16	.80

* $p < .05$, ** $p < .01$, *** $p < .001$
B = unstandardized beta coefficient, η_p^2 = partial eta squared

Table S11. Linear regression predicting age at death for participants supporting others in their social network, adjusted for covariates (n = 153)

Participants (G1)	B	p	95% CI of B		η_p^2 (%)
Intercept	17.23	***	9.45	25.01	6.00
Supported others	4.12	***	2.97	5.27	14.4
Comorbidity	-.12		-.54	.30	.10
Functional health	.18	*	.04	.33	2.10
Female	1.28	*	.26	2.29	2.00
Age	.77	***	.70	.84	62.1
Age at transition to grandparenthood	.03		-.02	.08	.40
Number of children	-.14		-.56	.27	.20
Number of grandchildren	.08		-.13	.30	.20
Without partner	.61		-.48	1.70	.40
Income	.17		-.16	.51	.30
Received support from others	-1.46		-2.99	.05	1.20
Interaction age × health	.01		.00	.18	.40

* $p < .05$, ** $p < .01$, *** $p < .001$
B = unstandardized beta coefficient, η_p^2 = partial eta squared

Interactions

It seems likely that age and health interact with each other the way they operate on the impact of caregiving on mortality. Indeed, this was the case (Table S12). Caregiving, age, comorbidity, functional health, and the interaction term (including age of participants and both health variables) significantly contributed to the prediction of mortality. Relative to model 1, the variance (R^2) explained by model 2, increased significantly when the interaction term was included ($p = .01$). Therefore, the interaction term was included in the main analyses.

Table S12. Linear regression models testing whether or not participants' age and health interact in the prediction of mortality

Model 1	β	p	B	95% CI of B		R^2
Caregiving	.09	.01	.45	.15	.76	45.2%
Age	-.42	.00	-.25	-.30	-.20	
Comorbidity	-.11	.01	-.32	-.53	-.11	
Functional health	.24	.00	.18	.12	.24	
Model 2						
Caregiving	.09	.01	.43	.12	.73	46.1%
Age	-.39	.00	-.24	-.29	-.18	
Comorbidity	-.04	.38	-.11	-.36	.14	
Functional health	.34	.00	.25	.17	.33	
Age × health	-.13	.01	-.16	-.19	.-.01	

We additionally tested for an interaction between caregiving and helpers' sex in the prediction of mortality, but found no significant interaction (Table S13). Relative to model 1, the variance (R^2) explained by model 2 did not increase significantly when the interaction term was included ($P = .43$). Therefore, the interaction term was not included in the main analyses.

Table S13. Linear regression models testing whether or not caregiving and helpers' sex interact in the prediction of mortality

Model 1	β	p	B	95% CI of B		R^2
Caregiving	.31	.00	1.40	1.01	1.78	9.40%
Sex	.12	.01	1.15	.37	2.12	
Model 2						
Caregiving	.21	.00	.92	-.25	2.13	9.50%
Sex	.08	.02	.78	-.68	2.24	
Sex × Caregiving	.11	.43	.38	-.55	1.30	

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5.3 Appendix C: Manuscript 3

A Prospective Study of the Relationship between Helping, Health, and Longevity

Sonja Hilbrand[1,2], David A. Coall[3,4], Andrea H. Meyer[1], Denis Gerstorf[5], Ralph Hertwig[2]

[1] Faculty of Psychology, University of Basel, Basel, Switzerland

[2] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

[3] School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

[4] School of Psychiatry and Clinical Neurosciences, University of Western Australia, Crawley, WA, Australia

[5] Department of Psychology, Humboldt University, Berlin, Germany

Corresponding author: Sonja Hilbrand, Faculty of Psychology, University of Basel, Missionsstrasse 60/62, 4055 Basel, Switzerland. Tel.: +41 61 267 04 40, s.hilbrand@unibas.ch

Abstract

Objective: How does helping behavior contribute to the health and the longevity of the helper? In our aging populations, understanding the mechanisms involved may illuminate valuable public health targets. From an evolutionary perspective, the ultimate mechanism for such an association may be rooted in ancient parenting and grandparenting which has generalized to a neural and hormonal caregiving system enabling prosocial behavior beyond the family. From a psychological perspective, helping others may be associated with healthy aging which contributes to longevity at a proximate level. Yet, little is known about the extent to which such health benefits translate into enhanced longevity, particularly in regard to grandparenting. To fill this gap, we examined whether or not grandparenting and helping behavior beyond the nuclear family contributed directly or indirectly (through better health 5-6 years later) to the longevity of older helpers.

Methods: Mediation analyses (structural equation models) were conducted on data from the longitudinal Berlin Aging Study ($N = 516$, mean age of participants = 85 years).

Results: Both moderate levels of grandparenting and helping beyond the nuclear family indirectly enhanced longevity significantly through better health. However, the mediation was incomplete and significant direct effects remained: Grandparenting and helping beyond the family both increased longevity independently of health. The results were robust against impacts of the helper's previous health status and sociodemographic characteristics of participants, their children, and grandchildren.

Conclusion: In order to tailor interventions promoting healthy ageing in contemporary industrialized societies, joint interdisciplinary forces are needed to unravel potential proximate mechanisms underlying the relationship between helping behavior and longevity.

Key words: Grandparenting, grandmother hypothesis, helping behavior, health, longevity

1. Introduction

Many societies around the globe are aging (Glaser et al., 2014). In Europe, for instance, the fastest growing segment of the population is aged 65 years or older. This group accounted for 15% of the total population in 2010 and is projected to comprise 25% in 2050 (WHO, 2012). At the same time, total fertility rate (TFR) has dropped from 2.3 children per woman in 1970 to 1.6 in 2014 (Eurostat, 2016) leading to a growing segment of childless individuals. One key issue in response to this demographic transformation is: How can healthy aging be promoted in older adults? A common strategy to stay active and healthy in old age is to provide childcare to grandchildren or – especially for childless individuals – supporting others in their social network and community. Both forms of helping behavior do not only substantially ease the pressure on the welfare and healthcare systems (Glaser et al., 2014; Gray, 2005), but they are also associated with reciprocal benefits in terms of better health or longer lifespan (Anderson et al., 2014, Hilbrand et al., 2016).

Most previous work has investigated helping behavior and its impact either on health or on survival, but not the paths between the three. In the present study, we examine and test these paths using evolutionary theorizing about ultimate mechanisms, complemented with predictions and previous findings from the behavioral sciences that provide a possible proximate explanation. Specifically, we investigate how grandparental caregiving as well as support beyond the family translate into health and eventually into longevity benefits.

With grandparenting and grandparental caregiving, we refer to non-custodial, non-intensive grandparental caregiving that is defined as time spent looking after a grandchild regardless of its age (Glaser et al., 2014). By supporting and helping others, we mean the provision of regular, but not extensive, instrumental or emotional support to members of the helper's social network beyond the nuclear family. Prosocial behavior relates to both grandparenting and supporting others.

1.1 Evolutionary perspective: Why helping behavior within and beyond the family may have enhanced the human lifespan

From an evolutionary perspective, an increased human lifespan is a bonanza: Having older people around who are healthy and willing to help with childcare improves the reproductive success of the dependents (see grandmother hypothesis, Hawkes et al., 1997; Hawkes and Coxworth, 2013). It is hypothesized that – at an ultimate level – helping behavior within and beyond kin is rooted in ancestral parenting and grandparenting (Brown et al., 2011; Chisholm et al., 2016; Hrdy, 2009) and is one of the driving forces underlying human longevity (Hawkes and

Coxworth, 2013; Kim et al., 2014). We briefly explain this evolutionary argument as it provides an ultimate explanation as to why humans have a strong tendency to help others and how this may be linked to longevity of helpers within and beyond the family. Note that the term ultimate refers to why and how a specific behavior evolved over hundreds of generations. The term proximate refers to mechanisms operating in immediate situations triggering specific behavior or consequences within an individual's lifespan.

Life history theory seeks to understand human behavior in specific environments by examining how evolutionary forces shaped the timing of distinct life phases and investment patterns (e.g., reproduction, grandparental investment and senescence). Within this framework, the grandmother hypothesis proposes that post-reproductive women who help to raise their grandchildren enhance their own inclusive fitness by improving the reproductive success of their children (Hawkes et al., 1997; Hawkes et al., 1998; Sear and Coall, 2011). Inclusive fitness (Hamilton, 1964) refers to the transmission of a person's genes into future generations via the person's own actions and those of kin who partially share the same genes (e.g., biological relatives).

Not only in ancient times (Hrdy, 2001, 2009) but also in contemporary natural fertility societies with high-fertility and high-mortality (Sear and Mace, 2008), it is crucial for grandchildren's survival to have helping grandparents around for as long as possible. As post-reproductive women still have functional physiological systems (except fertility), it is hypothesized that grandmothering slowed down somatic aging in humans across hundreds of generations (Hawkes and Coxworth, 2013). Grandparenting, especially grandmothering, is thus seen as conferring a selective advantage that drives human longevity (Kim et al., 2014). Does this selective advantage also relate to helping behavior beyond the family, and if so, how can this be explained?

Indeed, prosocial behavior may have extended beyond the family through parenting and grandparenting (Chisholm et al., 2016). Based on the neural circuitry involved in parenting (see Numan, 2006), prosocial behavior may have generalized to a neural and hormonal caregiving system developed throughout human evolution (Brown et al., 2011). This caregiving system is thought to be the ultimate foundation of caregiving towards non-kin that – at a proximate level – operates through emotional processes such as compassion and empathy. This would also be in line with the suggestion that empathy may have both a phylogenetic and ontogenetic basis in the emotional bond between parent and offspring (Preston and de Waal, 2002) but, when activated, extends beyond the family (Hrdy, 2009). These emotional pathways link helping behavior to regulatory physiological systems (e.g., stress-related neuro-hormonal systems, see Brown and Okun, 2014), which could be among the proximate mechanisms impacting health and longevity. Investigating proximate causes are more typically the domain of the behavioral sciences (de Waal, 2008). One of the behavioral science approaches, complementing evolutionary theorizing, is explained next.

1.2 Psychological perspective: Why older adults may benefit from prosocial behavior

Taking a psychological perspective, the socioemotional selectivity theory (SST) predicts that people will shift their goals from accumulating knowledge and skills at younger ages to maintaining social bonds at older ages (Carstensen, 1995). Shifting orientation towards and engaging in the latter is associated with healthy aging (Baltes and Carstensen, 1996; Ebner et al., 2006). Moreover, studies have shown that strengthening relationships with loved ones was key to maintain the quality of life in terminally ill patients regardless of age (Van der Maas et al., 1991; Wilson et al., 2004). Because physiological and cognitive aging signal the finiteness of life, prosocial behavior may be strengthened in older adults who focus on their social bonds. Increased helping behavior among older adults may thus indicate a shift towards emotional goals – a process involving compassion and empathy, linking behavior to the helper's physiological regulatory systems.

In older adults, the shift in orientation towards emotional goals (e.g., maintaining social bonds through helping) has been shown to be positively correlated with wellbeing (Ebner et al., 2006). This could be a proximate mechanism explaining benefits in health and longevity. A recent study points to this mechanism. Looking at stress-related mortality hazards in adults with a mean age of 71 years, Poulin and colleagues (2013) found that helping behavior towards friends, neighbors, or relatives who did not live with them overrides the link between stress and mortality: Although stress predicted mortality for non-helpers with a hazard ratio of 1.3, it did not predict mortality for helpers (hazard ratio = .96).

Most previous work has investigated helping behavior and its direct effects either on health or on survival, but not the links between the three, namely the indirect effect of helping on longevity through health. We briefly review what we know so far from the behavioral sciences about the interplay between helping, health, and longevity.

1.3 Benefits for the helper: Findings from the behavioral sciences

The moderate provision of childcare, for example, has been shown to be positively associated with grandparents' cognitive functioning (Arpino and Bordone, 2014), subjective wellbeing

(Mahne and Huxhold, 2015), and lower risk of depression (Grundy et al., 2012). Can older adults without children or grandchildren also gain such benefits, for instance, by allocating their potential for support to members in their social network or community?

Research on helping behavior beyond the family has indeed resulted in a large body of literature indicating that voluntarily supporting others has beneficial effects on a variety of the supporter's health outcomes (e.g., Brown et al., 2008; Kahana et al., 2013; Morrow-Howell et al., 2003; Musick et al., 1999; Tanskanen and Danielsbacka, 2016). Concerning older adults in particular, Anderson and colleagues (2014) reviewed 73 studies and found that for people aged 50 years and older, volunteering was consistently associated with reduced symptoms of depression, better self-reported health, fewer functional limitations, or enhanced longevity (for similar results, see Okun et al, 2013). The literature thus suggests that helping behavior has health or longevity benefits. However, it remains unclear whether longevity benefits are the result of the health benefits (indirect effects) or whether helping directly enhances longevity. Moreover, some boundaries to the beneficial effects of helping have been revealed as well.

To begin with, full-time grandparental caregiving, for instance, can be highly stressful and deplete grandparents' material and psychological resources and compromise their physical and mental health (Taylor et al., 2016). An inverse U-shaped relationship between the extent of grandparenting and wellbeing (Coall and Hertwig, 2010) is supported by findings from Glaser et al. (2014). They found that grandparents who co-reside with grandchildren (thus providing custodial childcare) as well as grandparents who do not provide grandchild care are more likely to report poor health. When speaking about the effects of grandparental caregiving, it is therefore important to quantify its intensity. Non-intense levels of caregiving are most likely to be associated with benefits reflecting the proposed curvilinear model. This may be especially true of older grandparents who may be more vulnerable to adverse effects of intense levels of caregiving. The same logic applies to help provided beyond the family. Helpers only benefit as long as their helping does not physically or psychologically exhaust them (Post, 2005). Furthermore, it is essential to take prior health and socioeconomic characteristics into account because associations between helping behavior and health outcomes are affected by these factors (Glaser et al., 2014; Hughes et al., 2007). When investigating helping behavior beyond the family, another issue is that the type and availability of formal volunteering often differs considerably among countries or regions (Stadelman-Steffen and Freitag, 2011). Therefore, it is useful to investigate a type of 'volunteering' that is prevalent in most communities, such as supporting others in the wider social network. Considering that decreasing fertility rates and more disability-free years will ultimately boost the numbers of older adults who do not have grandchildren to care for, but who are willing and able to allocate their resources to the care of others. This type of social support is especially valuable. Moreover, with demographic change (e.g., divorce and mobility), more grandparents, especially paternal ones, will not be in regular contact with their grandchildren but are able and possibly willing to provide support for others.

To eventually arrive at an encompassing analysis of the individual and collective effects of the potential benefits of helping behavior within and beyond the family, these issues need to be factored in. Our goal is to make some further steps toward such a comprehensive analysis.

Our brief review suggests that helping behavior at older ages – and under certain conditions – contributes to healthy aging, and thus indirectly to enhanced longevity. This pathway, however, has not been systematically investigated. Moreover, it remains unclear to what extent health benefits translate into enhanced longevity. Health may contribute strongly, but does it fully account for longevity benefits?

2. Hypotheses

Assuming that caregiving offered a selective advantage in humans' evolutionary past and that contemporary humans carry the genes for helping behavior, we showed in a previous study that the act of caregiving has measurable longevity effects for the helpers today (see Hilbrand et al., 2016). In the present study, we examine this association further.

Based on the assumption that human longevity is rooted in parenting and grandparenting (ultimate level), and that helping others is associated with better health in older adults (proximate level, see SST), we consequently examine whether helping behavior contributes indirectly (through better health) to longevity. Specifically, we formulated two hypotheses (see Figure 1). The first hypothesis states that the relationship between non-intensive grandparenting and enhanced longevity is mediated by better subsequent health. The second hypothesis poses that the relationship between moderate levels of support provided beyond the nuclear family and longevity is mediated by better subsequent health. In examining these hypotheses, we focused on older adults because health-related declines (e.g., cognitive abilities or functional health) become most salient with approximating death (Gerstorf et al., 2013; Kleemeier, 1962) and prosocial behavior may thus serve as a proxy to maintain social bonds for older adults.

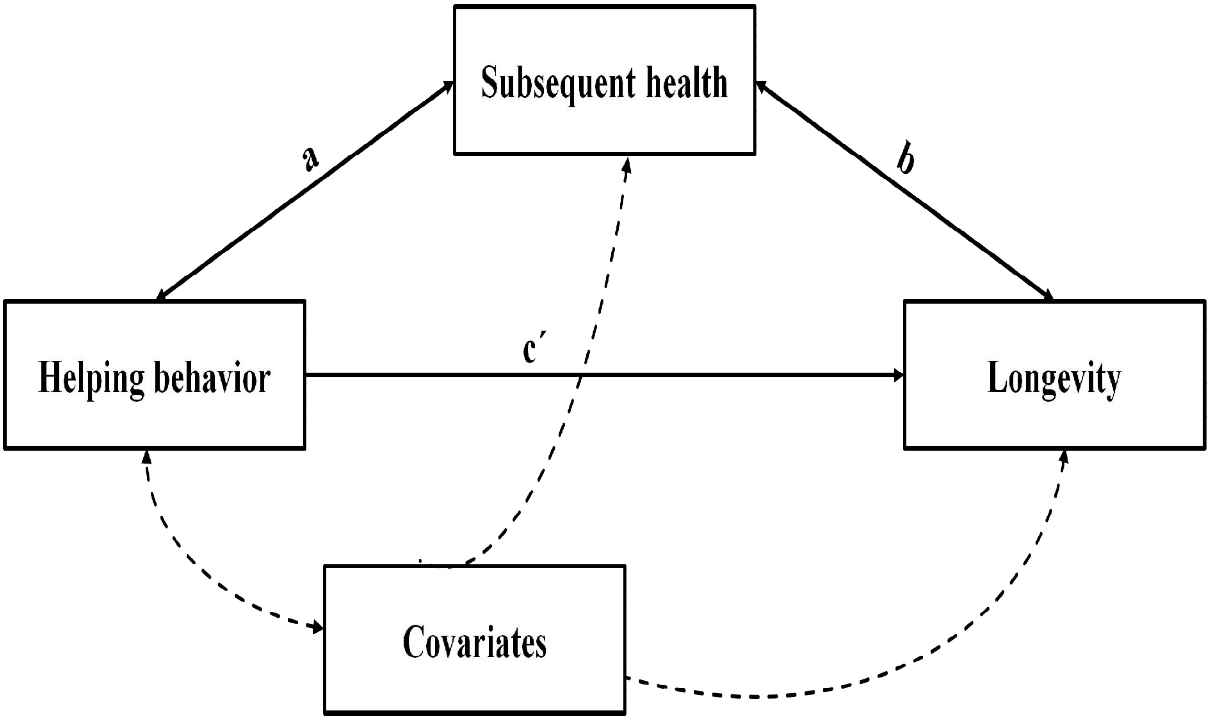

Figure 1. Mediation model of the relationship between helping behavior and longevity (direct effect, c´), mediated by health (indirect effect, ab), including covariates

3. Methods

3.1 Data

Data were drawn from the longitudinal Berlin Aging Study, BASE (Lindenberger et al., 2010). BASE is a multidisciplinary investigation of the physical, cognitive, and social characteristics of people aged 70 years and older living in the former West-Berlin. The BASE dataset contains extensive information on a range of health and social conditions obtained from the participants (generation 1, G1) as well as information provided by G1 about all of their children (generation 2, G2) and grandchildren (generation 3, G3). The BASE sample was randomly selected from the West-Berlin registration office records. Those who agreed to participate completed interviews and medical tests at their homes, doctors' practices, and hospitals. The assessments were repeated at approximately 2-year intervals between 1990 and 2009. Detailed descriptions of the variables and procedures used are available elsewhere (Lindenberger et al., 2010; see also https://www.base-berlin.mpg.de/en).

As is often the case in longitudinal study designs, most cases of longitudinal missing data were due to participant attrition (mortality or moving away from Berlin). The latest update on mortality in 2009 revealed that of the initial 516 participants 463 had died (89.7%), 33 were alive (6.4%), and 20 (3.9%) were unaccounted for. To avoid selection biases in favor of younger and healthier individuals (see Table S3 on sample selectivity in the supporting information, SI), we estimated all missing values using multiple imputation (IBM SPSS Missing Values 20, 2011). This procedure is recommended by Spratt et al. (2010), particularly for longitudinal data, such as in BASE. The estimation procedure resulted in thirty datasets with complete information on all variables used in subsequent analyses (for details, see the SI). The last survivor was estimated to have died in 2015.

3.2 Measurements

3.2.1 Dependent variable

Longevity was measured prospectively and indicates how many years participants lived following the interview at time 1 [T1] (known until 2009, estimated until 2015 when the last survivor was likely to have died).

3.2.2 Independent variables

Grandparenting indicates the frequency of grandparental caregiving in the twelve months prior to T1 and is defined as looking after or doing something with the grandchild (G3) without the parents (G2) being present. This variable ranges from 1 (never) to 7 (every day). Note that there were no cases of grandparental caregiving on a daily basis, in other words, our sample did not include any primary or custodial caregivers.

Supporting others indicates the sum of different kinds of supports given to others in the social network in the three months prior to T1. This included instrumental support (e.g., aid with housework, fixing things) and/or emotional support (e.g., comforting or cheering up someone). This variable ranges from 0 (no support given) to 6 (maximum number of supporting activities given). Note that the maximum number of support represents a moderate amount of help that is not expected to exhaust the helper. The six questions participants were asked are presented in the SI.

3.2.3 Mediator

Health index at interview time 3 [T3] is a Z-standardized composite scale representing subsequent health 5-6 years after T1. Because health is a multi-dimensional construct, we included four subscales reflecting physical and mental health: Comorbidity (number of physician-observed diagnoses), functional health (Instrumental Activities of Daily Living, IADL), cognitive functioning (Mini Mental State Examination, MMSE), and depression (Hamilton scale, HAMD). These subscales were selected via factor analysis. More details on these subscales and selection procedure can be found in the SI (Tables S1, S2).

3.2.4 Covariates

We controlled for a set of covariates across all three generations. The covariates have previously been shown either to influence longevity (Aichele et al., 2016; Gerstorf et al., 2013), health and aging (Lindenberger, 2014), or grandparental caregiving (Coall et al., 2009; Coall et al., 2014; Tanskanen and Danielsbacka, 2012).

At the participant level (G1), the covariates accounted for were as follows: *Health index at T1* (equivalent to health index at T3), *age, sex, relationship status, education level*, and *income*. *Age at transition to grandparenthood* was defined with respect to the birth of the first grandchild (this transitional age has been shown to be related to mortality, see Christiansen, 2014; Coall et al., 2009). The variable *number of children* also included children who had died in order to indicate family size units. The *number of grandchildren* included all living grandchildren to account for all potential caregiving opportunities. Finally, a variable coded the sum of different kinds of *support received* from others in their social network in the three months prior to T1 (equivalent to the sum of kinds of supports given to others as described above).

At the child level (G2), the covariates (averaged over all children), were *age, sex, education level*, and *relationship status*. At the participants' grandchild level (G3), the covariates were *age of the youngest grandchild* (because grandparenting is typically focused on the youngest), *sex, education level*, and *geographic proximity* to the grandparents (averaged over all grandchildren). Descriptive data on all measures are presented in Table 1. More details on the computation and coding of these variables are provided in the SI.

Table 1. Descriptive statistics of independent variables, mediator, dependent variable, and covariates (N = 516)

Participants (G1)	Mean or percentage	Range	n
Longevity (years)	6.52	0–22	516
Grandparenting	2.44	1–6	312
Supporting others	2.38	0–6	516
Health index at T3 (Z-standardized)	0	-1.52–1.78	516
Female	50.00%	–	516
Age	84.92	70–103	516
Age at transition to grandparenthood	57.22	31–89	312
Number of children	1.28	0–11	516
Number of grandchildren	1.83	0–22	516
Without partner	70.20%	–	516
Education level	1.56	1–5	516
Income	3.50	1–5	516
Received support from others	3.23	0–6	516
Health index at T1 (Z-standardized)	0	-1.56–1.85	516
Children (G2)			
Age	53.20	23–83	379
Female	42.00%	–	379
Education level	1.98	1-5	379
Without partner	35.50%	–	379
Grandchildren (G3)			
Age	19.41	0–46	312
Education level	1.65	1–5	312
Proximity	5.28	1–8	312

3.3 Statistical analyses

All analyses were conducted with SPSS v. 22.0 (IBM Corp. Armonk, NY, USA). First, variables with skewed distributions were logarithmically transformed. Second, model fitting indicated that linear rather than curvilinear associations were appropriate for investigating the relationship between grandparenting or supporting others and longevity (see Table S5 and Figure S1 and S2 in the SI). Third, we conducted a factor analysis extracting and testing the variables best representing the multi-dimensional construct of health (more details on this analysis are available in the SI, Table S1). In addition, we separately tested the predictive strength for each extracted health subscale on longevity and compared them to the cumulative effect of the health index at T3 (see the SI, Table S2). Fourthly, we computed correlation coefficients between the independent variables, the mediator, and dependent variables (see Table 2). Finally, we tested both hypotheses conducting adjusted multiple mediation analyses using the SPSS INDIRECT macro for mediation analysis by Hayes (update 2009). This procedure simultaneously calculates unstandardized regression coefficients for all paths of the mediation model thereby adjusting for the covariates in the model. Confidence intervals of coefficients denoting indirect effects are based on the bootstrapping sampling method (using 5,000 samples). Similar to regression coefficients in linear regressions, these coefficients indicate stronger associations with greater distance from 0 and positive associations are indicated by positive coefficients, negative associations by negative coefficients. We ran the macro separately for all thirty imputed datasets and aggregated the results, taking the variances within each set and between the sets into account (see Enders, 2010). In the first model testing hypothesis 1, grandparenting was the independent variable, the health index at T3 was the mediator, and longevity the dependent variable. Only grandparents were included in this analysis (n = 312). In the second model testing hypothesis 2, supporting others was the independent variable, the health index at T3 was the mediator, and longevity the dependent variable. Only childless participants were included in this analysis (n = 153) to ensure that the support did not go to children or grandchildren. Covariates in both models were socioeconomic characteristics at the grandparent, child and grandchild levels, and support received from others. Because grandparenting is correlated with supporting others in the social network, the latter was included as a covariate in model 1. In the last step, we tested the validity and robustness of the results and conducted both models using structural equation modeling functions as implemented in R software (R Development Core Team; Rosseel, 2012) on the basis of the original data. This procedure yielded very similar results to those from SPSS which are presented in Figure S3 and S4 in the SI. Complementary analyses (e.g., a mediation analysis with a sample restricted to grandchildren younger than 17 years or tests for interactions) are available in the SI.

4. Results

4.1 Link between helping behavior, health, and longevity

Correlational results (no covariates included) are presented in Table 2. Both independent variables (grandparenting and supporting others), the mediator (health index at T3), and the independent variable (longevity) were positively and significantly intercorrelated.

Table 2. Pearson correlations (r coefficients) between grandparenting, supporting others, health index, and longevity

	Grandparenting	Supporting others	Health index at T3
Grandparenting	1		
Supporting others	.67***	1	
Health index at T3	.70***	.63***	1
Longevity	.66***	.72***	.81***

*** p < .001

4.2 Mediating role of subsequent health

Model 1 tested the hypothesis that the relationship between grandparenting and longevity is mediated by subsequent health. Regression coefficients summarized in Figure 2 show that grandparenting indirectly contributed to longevity through better health: Higher levels of grandparenting were significantly associated with better health (a-path) and better health was significantly associated with increased longevity (b-path). The coefficient of the indirect effect (ab-path) thereby differed significantly from 0 (B = .20, 95% confidence interval (CI) = .01 - .23, p < .001). At the same time, the coefficient of the direct effect (c´-path) between grandparenting and longevity was also significantly positive. This means that the mediation was incomplete (subsequent health mediated 18.7% of the relationship between grandparenting and longevity). The model explained 86.5% of the total variance of longevity (adjusted R^2).

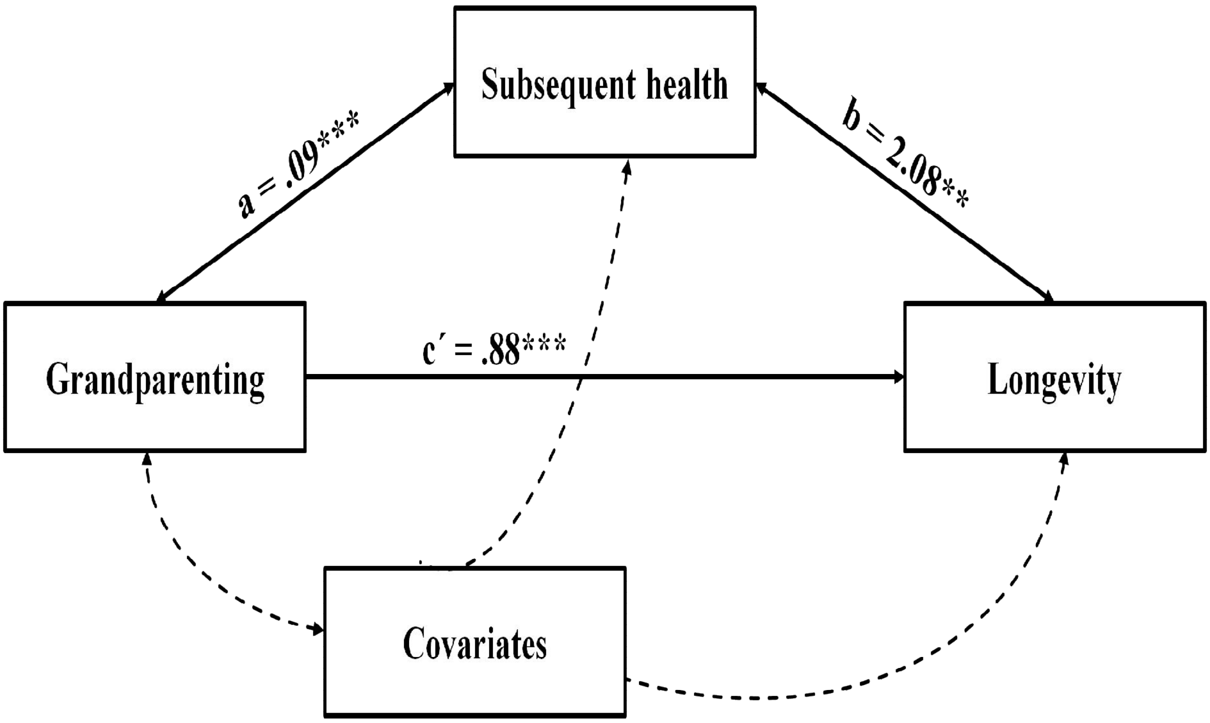

Figure 2. Regression coefficients from mediation model 1 testing indirect (ab) and direct (c′) effects of grandparenting on longevity, adjusted for covariates. Note ** p < .01, *** p < .001

Model 2 tested the hypothesis that the relationship between supporting others beyond the nuclear family and longevity is mediated by subsequent health. Regression coefficients summarized in Figure 3 again show that supporting others indirectly contributed to longevity through health: Higher levels of supporting others were significantly associated with better health (a-path) and better health was significantly associated with enhanced longevity (b-path). The coefficient of the indirect effect (ab-path) thereby differed significantly from 0 (B = .51, 95% CI = .28 - .84, $p < .001$). Again, the coefficient of the direct effect (c´-path) between supporting others and longevity was significantly positive. This means that the mediation was incomplete (subsequent health mediated 28.8% of the relationship between supporting others and longevity). The model explained 80.3 % of the total variance of longevity (adjusted R^2).

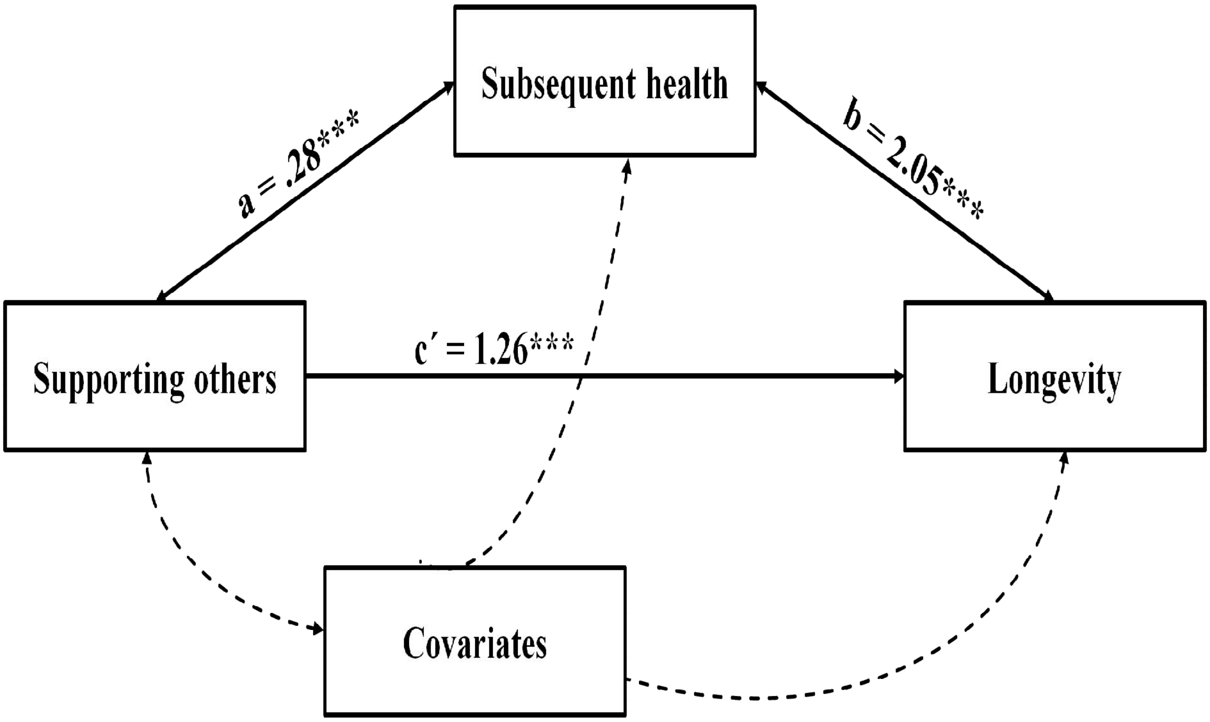

Figure 3. Regression coefficients from mediation model 2 testing indirect (ab) and direct (c´) effects of supporting others on longevity, adjusted for covariates. Note *** $p < .001$

Overall, grandparenting and supporting others beyond the family both were significantly associated with longevity and these associations were partially mediated by subsequent health. Among the subscales included in the mediator (health index at T3), the strongest impact on longevity was carried by functional health (see Table S2 in the SI).

5. Discussion

To the best of our knowledge, this is the first investigation to examine the pathways between helping behavior, health, and longevity on the basis of evolutionary theorizing about ultimate mechanisms and testing a proximate mechanism based on predictions from psychology. We consistently found that grandparenting as well as supporting others beyond the nuclear family were not only associated with increased longevity of the helper, but were partially mediated through better subsequent health. While most previous work has focused on health or longevity benefits, we investigated the links between them, drawn from our insights on evolutionary theory and psychology. We thus bridged interdisciplinary perspectives: Evolutionary theorizing (grandmother hypothesis and caregiving system) provides an ultimate explanation as to why helping behavior evolved to be associated with an increase in the human lifespan in the first place. Psychological theorizing (see socioemotional selectivity theory) provides a proximate explanation as to why particularly older adults may gain health and longevity benefits from helping others. However, better subsequent health did not fully mediate the relationship between helping behavior and longevity. Other potential candidates, not available in BASE, are discussed next.

5.1 Other factors associated with helping behavior and longevity

Although subsequent health and longevity were highly correlated (Pearson correlation, $r = .81$), health only mediated 18.69% of the relationship between grandparenting and 28.81% between supporting others and longevity in the adjusted models. This finding strongly suggests that the transmission of health benefits into enhanced longevity, often implicitly assumed in previous work, cannot be taken for granted. How can helping behavior increase longevity if it is not completely through health?

The measurement of health in the BASE study needs to be acknowledged first. Although health indices did include indicators of physical and emotional health (i.e., depression), indicators of stress were not available in BASE. Since emotional regulatory systems involve pathways linked to human stress-response, investigating stress and its triggers may further illuminate the link between helping behavior, health, and longevity. A recent study points to prosocial behavior as an effective strategy in reducing the impact of stress in everyday life because it influences biological systems, including stress-regulating hormones such as oxytocin (Raposa et al., 2016). This argument is in line with findings from Poulin et al. (2013) who found helping behavior to be a stress buffer that in turn boosted survival. Both studies complement the evolutionary argument that the ultimate foundation of the human caregiving system evolved from (grand)parenting and proximately operates through emotion (e.g., compassion) and stress regulatory systems (e.g., oxytocin), thus influencing health and longevity.

Another factor potentially involved in the link between helping behavior and longevity is the relationship between care provider and receiver. For example, maintaining quality contact with paternal grandparents who are often alienated during re-partnering and step-family formation is beneficial to the behavioral adjustment and mental health of both grandparents and grandchildren (Attar-Schwartz et al. 2009; Bates and Taylor, 2012). Social strain afflicting intergenerational relationships not only leads to declines in health (Tun et al., 2013), but also decreases the probability of helping behavior in these relationships (Coall et al., 2014). Therefore, emotional relationship quality may moderate the relationship between helping and longevity (Merz et al., 2007).

Participants' motives for helping may also play a key role in whether or not helping behavior results in health and longevity benefits. These benefits have previously been found only when volunteering was other-oriented but not reciprocity-oriented (Konrath et al., 2012). From an evolutionary perspective, it is plausible that other-orientation evolved within the family (see caregiving system). It follows that the engine behind helping behavior is not primarily reciprocity based (see Kurzban et al., 2015 for a review of human altruistic behavior). Indeed, results from health psychology suggest that frustrated expectations of reciprocal reward can override positive effects of helping and may even lead to depression for the helper (Keller, 2002). Thus, whether or not the help provided is other- or reciprocity-oriented may further shape the relationship between helping and longevity.

These bio-psycho-social factors may play an important complementary role in the relationship between helping behavior, health, and longevity. The examination of multiple proximate pathways may reveal a more detailed picture of causal mechanisms underlying the relationship between helping within and beyond the family and longevity. In this study, a first step was taken. Strengths, limitations, and future directions are discussed next.

5.2 Strengths, limitations and future research

This investigation has several strengths. First, we brought together evolutionary and psychological theorizing, showing that they complement rather than compete with each other in explaining how helping, health, and longevity relate to each other. Using interdisciplinary approaches in future research may further illuminate these links.

Second, we included both physical and mental health proxies to reflect the multi-dimensional construct of health. Focusing on one aspect of health would probably not be sufficient to detect effects on longevity as physical and mental health cumulatively impact longevity (Aichele et al., 2016, see also Table S2 in the SI for additional analyses on each health subscale). We also note that our health measures were not only based on self-reports, but also involved the number of physician-observed diagnoses (determined in clinical examinations supported by additional blood and saliva laboratory assessments) of moderate to severe chronic illnesses and performance-based measures of cognitive functioning. Additionally, we were able to make use of the longitudinal nature of the BASE dataset, permitting prospective investigation of how helping behavior at T1 was associated with subsequent health at T3 and consequently impacted longevity. BASE also allowed us to account for prior health and socioeconomic characteristics of participants, all of their children and grandchildren (in contrast to many studies in which the closest or youngest grandchild was chosen). Taking these characteristics into account across all three generations provides a more detailed representation of the helpers and their social and familial networks than achieved by many previous studies.

Third, the BASE dataset allowed us to account for support received from others, thus controlling for reciprocity. Receiving support in old age is hypothesized to contribute to longevity independently of health. Specifically, grandparents are more likely to allocate their resources to those grandchildren who are most likely to reciprocate (see rational grandparent model, Friedman et al., 2008), thus ensuring grandparental wellbeing in old age. Because we have controlled for support received in both models, this competing explanation can be ruled out. Furthermore, from an evolutionary perspective, it is the provision of help that translates into health and longevity benefits, rather than receipt alone (Brown et al., 2003).

We acknowledge several limitations of our study. As mentioned above, additional bio-psycho-social factors such as stress-related hazards, the motivation to provide care or relationship quality may play a crucial role regarding helping behavior and longevity. These factors were not available in BASE and we could not explore their impact.

It is also possible that helping behavior is associated with longevity in younger and healthy but not in older and less healthy people. We tested for an interaction between age and health (see the SI). Indeed, younger and healthier participants were more likely to benefit from helping. Therefore, we included an interaction term (age × health) in both models. Results remained robust against the influence of the interaction, that is, longevity benefits were not due to younger age and better prior health.

Another limitation of this study is that we did not take childhood events of the participants into account. This could have created a more detailed picture of how earlier advantages/disadvantages play out in the lives of older adults. For example, it was possible that growing up in an environment where care had been common and no severe life events had happened, advantages accumulated over time, leading to better health and enhanced longevity. Regarding our sample, although they were selected at random, it is more likely that most of the participants (aged 70 and older) living in the former West-Berlin between 1990 and 2009 have experienced rather harsh living environments in their childhood during and after World Wars I and II. With this in mind, it could be speculated that helping behavior may even buffer some of the accumulated disadvantages of our sample. This would be in line with Glaser et al. (2014) who found that "Providing non-intensive childcare has a positive effect on grandparents' health, even after their previous health and socio-economic status and childhood and adulthood experiences of advantage and disadvantage are taken into account" [p.8].

These findings raise the question whether promoting helping behavior within and beyond the family was a cost effective and sustainable pathway to healthy ageing and longevity. From both the evolutionary and the psychological perspective, the answer is yes. Future large scale, longitudinal studies need to examine whether, and to what extent, helping behavior may constrain health care costs of the older members of our societies.

5.3 Conclusion

Our findings suggest that helping behavior not only enhances longevity, but also supports *healthy* ageing in particular. From the perspective of health care, this is good news. Older adults engaged in helping behavior means that society is not simply aging, but is aging actively and healthier. In order to tailor interventions promoting healthy aging in contemporary industrialized societies, however, joint interdisciplinary efforts are needed to unravel more detailed proximate mechanisms underlying the relationship between helping behavior and longevity.

Last but not least, health economists have proposed that health costs are highest with impending death, independent of age (Breyer et al., 2010). As death is inevitable for all of us, the question is not if we can postpone this moment but how socially engaged and healthy we live our lives until death's door.

Competing interests

We have no conflict of interest.

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Supporting information to manuscript 3

In this document, we explain our analyses in more detail. First, we provide details on the computation and coding of the measures. Second, the results of the factor analysis are presented in Table S1. In addition, in Table S2, results of the linear regression analyses are presented showing the predictive strength for each extracted health subscale on longevity, compared to the cumulative effect of the *health index*. Third, we discuss sample selectivity of the BASE dataset and compare characteristics of participants who were still alive in 2009 with those who had died (Table S3). Fourth, we describe how we estimated missing data for all variables used in this study (Table S4). Fifth, we tested for a possible quadratic relationship between both forms of helping behavior and longevity. To this end, we specified regression models estimating a linear relationship and compared it with fitted quadratic regression models (Figure S1, S2, and Table S5). Sixth, we present results from the mediation analyses conducted with the R software in Figure S3 and S4. Seventh, an additional mediation analysis using a sample restricted to grandchildren younger than 17 years is presented in Figure S5. Finally, we report analyses testing for possible interactions between health and age (Table S6 and S8) and helping behavior and participants' sex (Table S7, S9). In Figure S6 and S7, results testing the findings from the main analysis against the influence of relevant interactions are shown.

Details on computation and coding of measures

In BASE, data on children and grandchildren are presented in person-point format (long format), meaning that each participant has multiple entries depending on how many children and grandchildren they have. Participants without children appear only once in the dataset. In order to have each participant represented equally in the sample, we aggregated the data of those with multiple entries. In the following, we provide additional information on some of the variables used in our analyses and define how the data was aggregated for variables affected by the long format (if not stated in the main text).

Independent variables: Frequency of *grandparenting* was measured by the question "How often have you looked after [name of grandchild] in the past year or done something with him/her without the parents being present?" This question was asked for each grandchild. Answers were recoded into 7 = "every day," 6 = "several times a week," 5 = "once a week," 4 = "once a month," 3 = "several times a year," 2 = "less often," 1 = "never". For those participants who had several grandchildren the frequency of caregiving was averaged across all grandparent-grandchild dyads. By definition, non-grandparents cannot care for biological grandchildren. Nevertheless, participants (G1) with grandchildren (G3) to whom they were not biologically related were still considered as grandparents in our study. Participants with biological or non-biological grandchildren were coded as 1 = *caregiving grandparents* if they reported any caregiving (n = 80) and 2 = *non-caregiving grandparents* if they did not (n = 232). *Childless participants* were coded as 3 (n = 153). Participants who reported having children but no grandchildren (n = 51) were not included in the analyses.

The variable indicating how much emotional or instrumental support was given to others in the social network was not affected by the long format and no aggregation was necessary. Participants were asked about six different kinds of support given to others in the past three months. The variable *supported others* indicates the sum of the six questions answered with yes: (1) "Did you help anyone with his or her household chores, i.e. cleaning up or fixing something?" (2) "Did anyone confide in you about personal matter, i.e. about problems or worries?" (3) "Have you helped anyone with his shopping or gone on other errands for him or her?" (4) "Did you cheer up anyone when he or she was feeling down?" (5) "Did you hug anyone, give him or her a kiss, or show any other gestures of fondness towards him or her?" (6) "Is there anybody whom you care for, who is confined to bed indefinitely?".

Mediator: As health is a multidimensional construct, we utilized four subscales reflecting physical and mental health. The subscales included in the *health index at T3* were selected via factor analysis (see Table S1). Note that the mediator at T3 (out of T2 - T8) was chosen because (1) all necessary health items were collected at T3 (which was not the case at all measurement points) and (2) there were not more than 35% missing cases per variable (see Spratt et al., 2010), which made multiple imputation still reliable (at T4 or later participant attrition was much higher due to mortality).

All subscales were Z-standardized before being summed up to calculate the variable *health index at T3*. The subscales are described as followed: 1) the extent of *comorbidity* was measured as the number of physician-observed diagnoses (as determined in clinical examinations, supported by additional laboratory analysis of blood and saliva samples) of moderate to severe chronic illnesses (according to the International Classification of Diseases, 9th Revision, ICD-9, see WHO, 1979). This variable was recoded so that higher numbers indicate better health (less diagnoses). 2) to measure *functional health*, we used the Instrumental Activities of Daily Living (IADL) scale (Lawton and Brody, 1969). This scale measures independent living skills such as housework and shopping, with higher IADL scores indicating better health. It is especially recommended for observing individual decline over time (Graf, 2013; Myers, 1992). 3) to reflect *cognitive functioning*, we relied on the Mini Mental State Examination (MMSE, Folstein et al., 1975). It has achieved wide spread use in clinical and research settings to measure cognitive impairment and the course of cognitive changes in an individual over time. The scale ranges from 0-30 with a higher score meaning better cognitive functioning. 4) to measure the extent of depressive symptoms, we used the Hamilton rating scale for depression (HAMD, Hamilton, 1960). This self-rating screening instrument is widely used in clinical and research settings to initially measure depression and changes in severity over time (Nutt, 2014). The scale ranges from 0 to 66 (version with 21 items) where higher scores mean better mental health (less depressive symptoms).

Covariates: Representing previous health status of participants, the *health index at T1* was calculated equivalently to T3 (with the four Z-standardized subscales comorbidity, IADL, MMSE, and HAMD at T1). A Cronbach's alpha of .57 indicated sufficient internal consistency. The *number of grandchildren* was calculated by summing up all grandparent-grandchild dyads for each grandparent. *Participants' sex* was coded as 1 (male) or 2 (female). *Children's sex* was aggregated across all dyads and then split into "most or all male" (0) and "most or all female" (1). *Relationship status* of participants and their children were recoded into 1 = with partner, 2 = without partner (including single, widowed, and divorced status). When there were several children, information on their relationship status was aggregated across all dyads and then split into most or all children have a partner (0) and most or all children have no partner (1). *Education levels* were available for participants, children, and grandchildren (averaged over all children and grandchildren) and ranged from 1 = low to 5 = high. The variable *income* represents participants' monthly net income per capita in deutsche mark (DM), weighted by the number of household members, and was grouped into five categories: 1 (<1000), 2 (1000–1399), 3 (1400–1799), 4 (1800–2199), and 5 (> 2200). Geographic *proximity* to grandchildren was recoded into 1 = same household, 2 = same house/building, 3 = neighborhood, 4 = same district, 5 = different district, 6 = different province, 7 = different European country, and 8 = different continent. This variable was averaged across all grandparent-grandchild dyads.

Health index at T3: Factor analysis and predictive strength of each subscale

The subscales included in the *health index* at T3 were selected via factor analysis (see Table S1). Only one component was extracted with all four subscales sufficiently loading on. The mediator reached sufficient internal consistency with a Cronbach's alpha of .61.

Table S1. Results of the factor analysis extracting one component with four health subscales representing physical and mental health in the *health index* at T3

Health subscales	Loading on extracted component
Comorbidity (number of diagnoses)	.62
Functional health (IADL)	.85
Cognitive functioning (MMSE)	.66
Depression (HAMD)	.83

Next, we separately explored the predictive strength for each selected subscale on longevity via linear regression analyses (Table S2). Health subscales at T3 were used as independent variables while the equivalent subscale at T1 was controlled for.

Results indicate that functional health (IADL) was the most predictive factor for longevity. Finally, we conducted a regression analysis with the *health index at T3* as the independent variable (using the *health index at T1* as the control variable). Results show that the *health index at T3* cumulatively explains much more of the variance in predicting longevity than each of the subscales alone.

Table S2. Results of the linear regression analyses testing predictive strength for each health subscale on longevity, compared to the cumulative power of the *health index* at T3

Independent variables at T3	B	p	95% CI (B)		Partial eta squared
Comorbidity (number of diagnoses)	.07	.06	-.29	.43	.00
Functional health (IADL)	1.81	.001	.77	2.86	.02
Cognitive functioning (MMSE)	.30	.02	.06	.55	.01
Depression (HAMD)	.15	.01	.03	.27	.01
Health index (including all subscales)	4.58	.000	4.17	5.00	.46

Sample selectivity

As was to be expected, the sample that completed the full BASE protocol was positively selected. For example, participants who completed the full set of interviews and medical examinations showed lower mortality rates than those who did not. However, selectivity analyses have shown that mean variations in the analyzed sections (e.g. sociodemographics, intelligence, health) were always below one standard deviation. Thus, there is no indication for strong systematic patterns of variation between the participants who completed the full protocol and those who did not. Hence, the sample can be considered to be representative (for more details on selectivity analyses, see Lindenberger et al., 2010).

We explored sample selectivity in more detail by comparing participants who were still alive in 2009 with those who had died (Table S3). We conducted independent-samples t-tests for scaled variables, Mann–Whitney U tests for ordinal data, and Chi-squared tests for nominal variables. At T1, participants who were still alive in 2009 were significantly more often caregiving grandparents than non-caregiving grandparents, more often supported others in their social network, showed better health at T1 and T3, were younger and more often female, had a higher income, less often received support from others, and they had younger children and grandchildren. The children of the still-alive participants were more often female and without a partner.

As we estimated mortality dates and all values of other missing data for all 516 participants, we were able to make use of the total sample and not only of those who had died by 2009.

Table S3. Sample selectivity: Comparison of living and deceased participants in 2009 (N = 496 because 20 participants were unaccounted for in the original data)

	Living participants (n = 33)				Deceased participants (n = 463)			
Participants (G1)	Percentage or mean	Range	SD	n	Percentage or mean	Range	SD	n
Caregiving grandparents**	35.00%	–	–	14	13.10%	–	–	66
Non-caregiving grandparents**	30.00%	–	–	12	46.40%	–	–	220
Childless participants	20.00%	–	–	8	30.50%	–	–	145
Supported others**	90.90%	–	–	28	66.70%	–	–	328
Health index at T1 (Z-standardized)**	1.00	-.75–1.83	.66	20	-.08	-1.56–1.85	.98	476
Health index at T3 (Z-standardized)**	1.03	-.87–1.76	.73	24	-.09	-1.08–1.81	.97	323
Age***	75.21	70–84	4.21	33	85.88	70–103	8.36	463
Female*	63.60%	–	–	22	49.00%	–	–	236
Income*	3.96	1–5	1.24	33	3.49	1–5	1.34	463
Age at transition to grandparenthood	56.42	31–79	9.98	33	57.19	39–89	8.57	436
Number of children	1.50	0–7	1.46	33	1.25	0–11	1.32	463
Number of grandchildren	1.58	0–10	2.33	33	1.81	0–22	2.48	463
Without partner	66.70%	–	–	23	70.80%	–	–	339
Education level	1.45	1–4	.71	33	1.51	1–5	.81	463
Received support from others*	72.70%	–	–	28	88.10%	–	–	419
Children (G2)								
Age***	46.40	33–71	7.44	33	54.05	13–83	9.92	463
Female*	67.00%	–	–	20	29.2%	–	–	105
Without partner*	67.20%	–	–	21	34.20%	–	–	109
Education level	3.79	2–5	1.00	33	3.38	1–5	1.43	463
Grandchildren (G3)								
Age**	13.47	0–38	10.25	33	20.22	0–46	11.01	463
Proximity	5.29	2–8	1.20	33	5.26	1–8	1.09	463
Education level	3.46	1–5	4.08	33	3.50	1–5	2.61	463

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

Estimation of missing data

In order to avoid selection biases in favour of younger and healthier individuals (see sample selectivity above), missing information was estimated using multiple imputation. This procedure is recommended by Spratt et al. (2010), particularly for longitudinal data such as in BASE. According to Spratt et al. (2010), estimating missing information (including the dependent variable) is preferred over loosing cases due to missing information. With this procedure, missing information is estimated based on observed data and random noise is then added in order to achieve reasonable variance. To reduce bias in the estimation process, dependent and independent variables, mediator, covariates, and additional variables available in BASE were used. We included extra health indicators such as Activities of Daily living (ADL) or grip strength and sociodemographic data such as social class of participants and their adult children as additional variables. Spratt and colleagues (2010) recommend producing as many datasets as the highest percentage of missing values. Because the items used to calculate the *health index* at T3 (comorbidity, IADL, MMSE, HAMD) had 30% missing values, the estimation procedure was specified to produce thirty datasets with complete information on all variables used in subsequent analyses (except for group variables, i.e., grandparents, n = 312). The mediation models were run separately for all datasets and results were aggregated, taking variance within each set and between the sets into account (see Enders, 2010). Percentages of estimated missing values on each variable used in the main analysis are presented in Table S4.

Table S4. Percentage of missing data estimated for dependent and independent variables, mediator, and covariates

Participants (G1)	Percentage missing
Longevity (years)	10.30
Grandparenting	0
Supporting others	0
Health index at T3 (Z-standardized)	30.07
Female	0
Age	0
Age at transition to grandparenthood	7.79
Number of children	0
Number of grandchildren	0
Without partner	0
Education level	.88
Income	13.01
Received support from others	0
Health index at T1 (Z-standardized)	0
Children (G2)	
Age	1.85
Female	0
Education level	5.02
Without partner	2.64
Grandchildren (G3)	
Age	5.12
Education level	21.54
Proximity	2.25

Testing for a possible quadratic association between helping behavior and mortality

To examine the nature of the relationship of both grandparenting (model 1) and supporting others (model 2) with longevity we compared linear regression models with quadratic regression models. Visual inspection of the fitted curve (Figure S1, S2) of the quadratic models may suggest that a quadratic function fits the observed data better than a linear one. As summarized in Table S5, longevity increases with increases in levels of helping behavior (B1) until a certain point is reached. From this point on, helping behavior starts to negatively impact longevity (B2). However, in both models there was no significant increase in overall model fit (R^2) when the quadratic function was added to the linear models and only the linear models remained significant. This means that the assumption of a linear relationship between both forms of helping behaviour and longevity is adequate and that it is appropriate to apply linear statistical procedures to the data used in this study.

From a theoretical point of view, it is likely that intense levels of helping behaviour would decrease longevity (Glaser et al., 2014; Post, 2005). In our sample, we had no cases of daily grandparenting or extreme levels of supporting others. This may be the reason why the quadratic function did not provide a significant improvement in fit over the linear model.

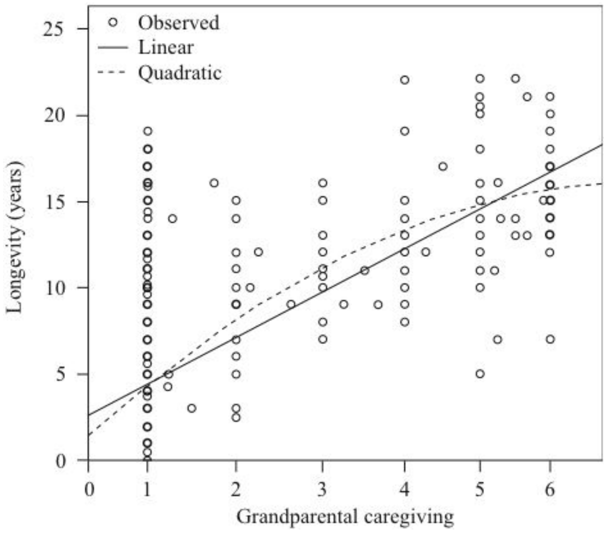


Figure S1. Model fit of linear and quadratic relationships between grandparenting and longevity

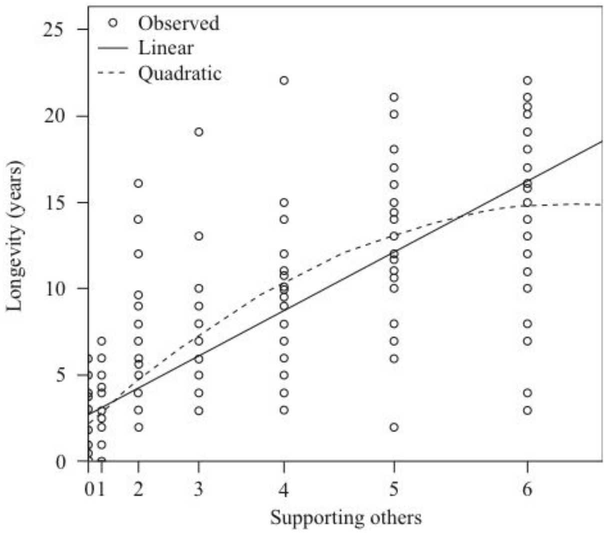


Figure S2. Model fit of linear and quadratic relationships between supporting others and longevity

Table S5. Curve comparison with linear and quadratic functions assumed between helping behavior and longevity

Equation	B1	B2	p	F	df1	df2	R^2
Model 1 Grandparenting							
Linear	4.27	–	.00	31.59	1	459	.062
Quadratic	6.81	–2.11	.19	16.69	2	458	.064
Model 2 Supporting others							
Linear	5.37	–	.00	1360.74	1	514	.073
Quadratic	7.63	–.01	.14	777.40	2	513	.075

Mediation analyses conducted with the R software

To test whether the results of the mediation analyses conducted across the 30 multiple imputation files in SPSS were valid, we calculated both mediation models with R (using the structural equation model package). The R software is able to run the mediation analyses while estimating the missing values. Thus, these models were conducted on the basis of the single original dataset including missing data. The R procedure yielded similar results (Figure S3, S4) to SPSS indicating that they are valid and robust results (compare with Figure 2 and 3 in the main analysis).

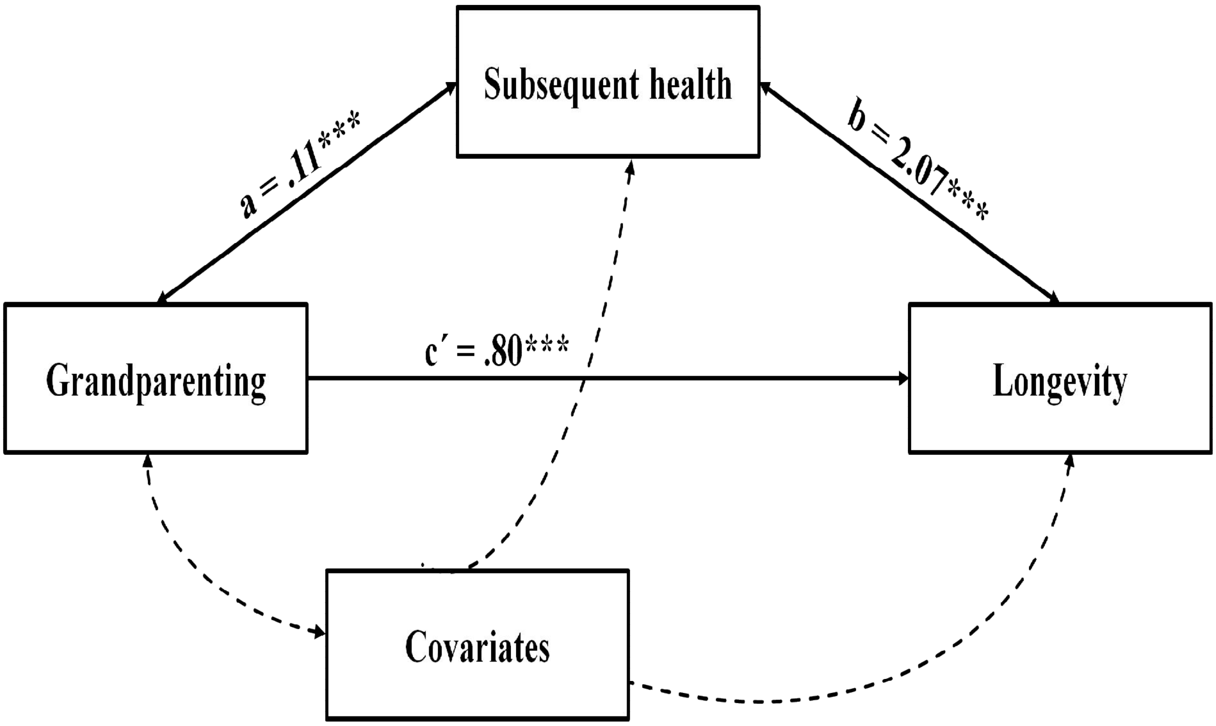


Figure S3. Regression coefficients from mediation model 1 testing indirect (ab) and direct effects (c′) of grandparenting on longevity (results from R), adjusted for covariates

Note *** p < .001

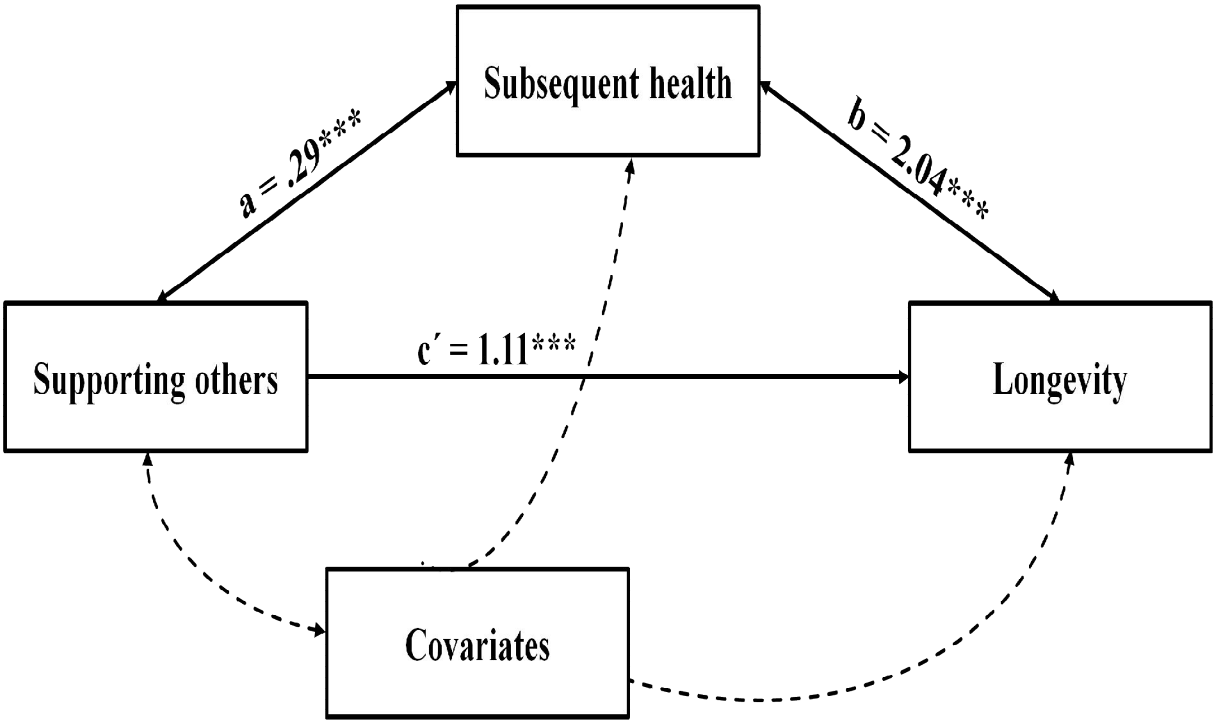


Figure S4. Regression coefficients from mediation model 2 testing indirect (ab) and direct effects (c′) of supporting others on longevity (results from R), adjusted for covariates
Note *** p < .001

Additional mediation analysis restricted to grandchildren younger than 17 years

Looking after grandchildren is usually associated with younger grandchildren. In our sample, the grandchildren of caregiving grandparents were significantly younger than those of non-caregiving grandparents. This increased the likelihood of grandparenting for the first group.

To further test the robustness of our findings, we conducted the mediation analysis with grandparenting (model 1) with a sample restricted to grandchildren younger than 17 years (using the oldest grandchild of caregiving grandparents as the upper limit, n = 128). Results (see Figure S5) confirm those reported in the main analysis (compare Figure 2 in the main analysis), suggesting that the association between grandparenting and longevity was robust to grandchild age. However, the effect of grandparenting on health (a-path) was accelerated while the effect of health on longevity (b-path) was weakened, but remained significant. Moreover, the direct effect of grandparenting (c′-path) was also accelerated, indicating that the health and longevity benefits of providing childcare to younger grandchildren are stronger than providing care to older grandchildren.

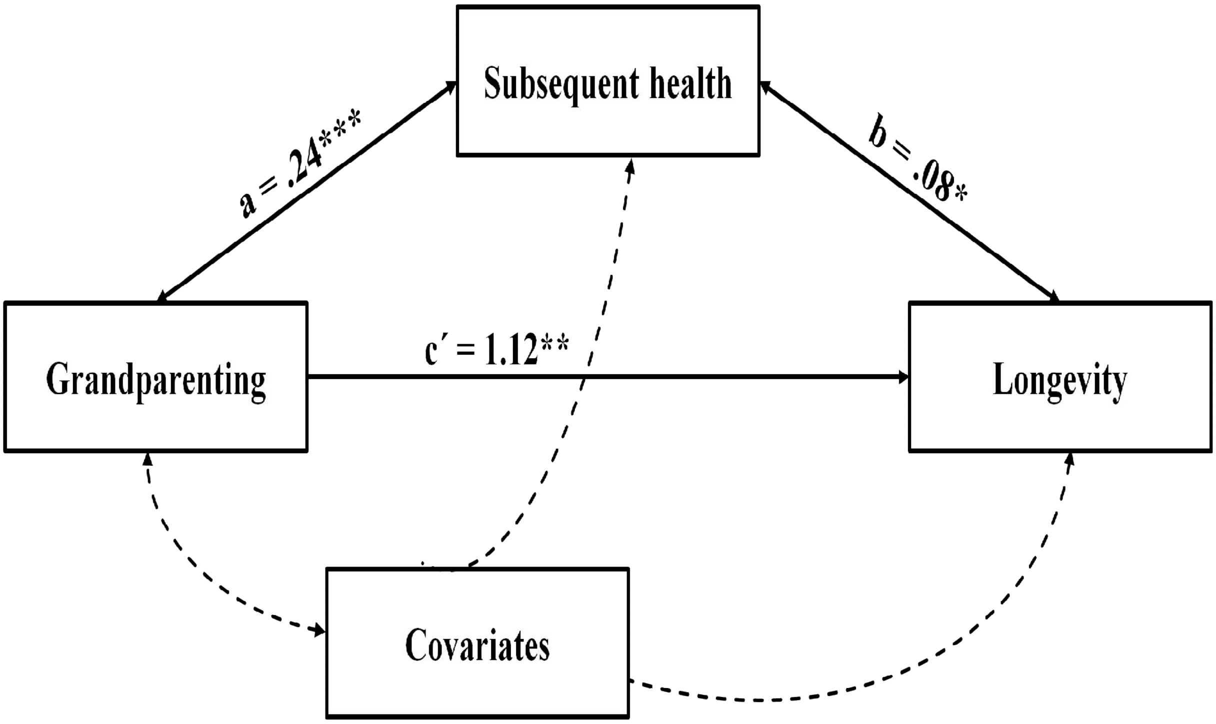


Figure S5. Regression coefficients from mediation model 1 testing indirect (ab) and direct effects (c′) of grandparenting on longevity (only grandchildren younger than 17 years included), adjusted for covariates. Note * $p < .05$, ** $p < .01$, *** $p < .001$

Interactions

It seems likely that age, health, and sex interact with each other on the impact that helping behavior has on longevity. We tested these relevant interactions for both grandparenting and supporting others (Tables S6–S9). Finally, we tested our findings from the main analysis against the effects of relevant interactions by including them as covariates (Figure S7, S9).

Grandparenting, age, health, and the interaction term (age × health) significantly contributed to the prediction of longevity (Table S6). Relative to model I, the variance (R^2) explained by model II, increased significantly when the interaction term was included ($p < .00$).

Table S6. Linear regression models testing whether grandparents' age and health interact in the prediction of longevity

Model I	β	p	B	95% CI of B		R^2
Grandparenting	.38	.00	1.20	1.03	1.37	
Age	-.10	.00	-.07	-.10	-..03	77.4%
Health index at T1	.52	.00	2.89	2.55	3.22	
Model II						
Grandparenting	.34	.00	1.09	.92	1.26	
Age	-.12	.00	-.07	-.11	-.04	78.2%
Health index at T1	1.60	.00	8.90	6.25	11.55	
Age × health	-1.07	.00	-.07	-.10	.-.04	

We additionally tested for an interaction between grandparenting and grandparents' sex in the prediction of longevity, but found no significant interaction (Table S7). Relative to model III, the variance (R^2) explained by model IV did not increase when the interaction term was included (p = .78).

Table S7. Linear regression models testing whether grandparenting and grandparents' sex interact in the prediction of longevity

Model III	β	p	B	95% CI of B		R^2
Grandparenting	.76	.00	2.41	2.23	2.59	57.7%
Sex	.05	.11	.51	-.12	.14	
Model IV						
Grandparenting	.79	.00	2.48	1.94	3.03	
Sex	.06	.20	.62	-.33	.56	57.7%
Sex × grandparenting	-.03	.76	-.05	-.41	.31	

Next, we tested for a possible interaction of age and health in the prediction of longevity with regard to supporting others (Table S8). Supporting others, health, and the interaction term (age × health) significantly contributed to the prediction of longevity. Relative to model V, the variance (R^2) explained by model VI significantly increased when the interaction term was included (p = .01).

Table S8. Linear regression models testing whether supporters' age and health interact in the prediction of longevity

Model V	β	p	B	95% CI of B		R^2
Supporting others	.61	.00	1.59	1.38	1.80	
Age	-.03	.25	-.02	-.05	.01	78.3%
Health index at T1	-.28	.00	1.58	1.15	2.02	
Model VI						
Supporting others	.56	.00	1.47	1.266	1.68	
Age	-.05	.05	-.03	-.07	.00	79.5%
Health index at T1	1.56	.00	8.72	6.16	11.28	
Age × health	-1.26	.00	-.08	-.11	-.05	

Last, we tested for an interaction between supporting others and supporters' sex in the prediction of longevity, but found no significant interaction (Table S9). Relative to model VII, the variance (R^2) explained by model VIII did not increase significantly when the interaction term was included (p = .13).

Table S9. Linear regression models testing whether supporting others and supporters' sex interact in the prediction of longevity

Model VII	β	p	B	95% CI of B		R^2
Supporting others	.87	.00	1.40	2.17	2.39	7.60%
Sex	-.03	. 61	1.15	-.81	.14	
Model VIII						
Supporting others	.97	.00	.92	2.18	2.89	
Sex	.01	.84	.78	-.63	.78	7.60%
Sex × Supporting others	-.11	.12	.38	-.39	.05	

To test whether the interactions found to be relevant (age × health with regard to grandparenting and supporting others) impacted our main findings, we included them in additional mediation models. Results presented in Figure S6 and S7 show that our main analysis' findings were robust against interaction effects (compare with Figure 2 and Figure 3 in the main analysis). In model 1 (grandparenting), the interaction term did not show a significant impact (p = .13). The same was true for model 2 (supporting others), the interaction term did not show a significant impact (p = .21).

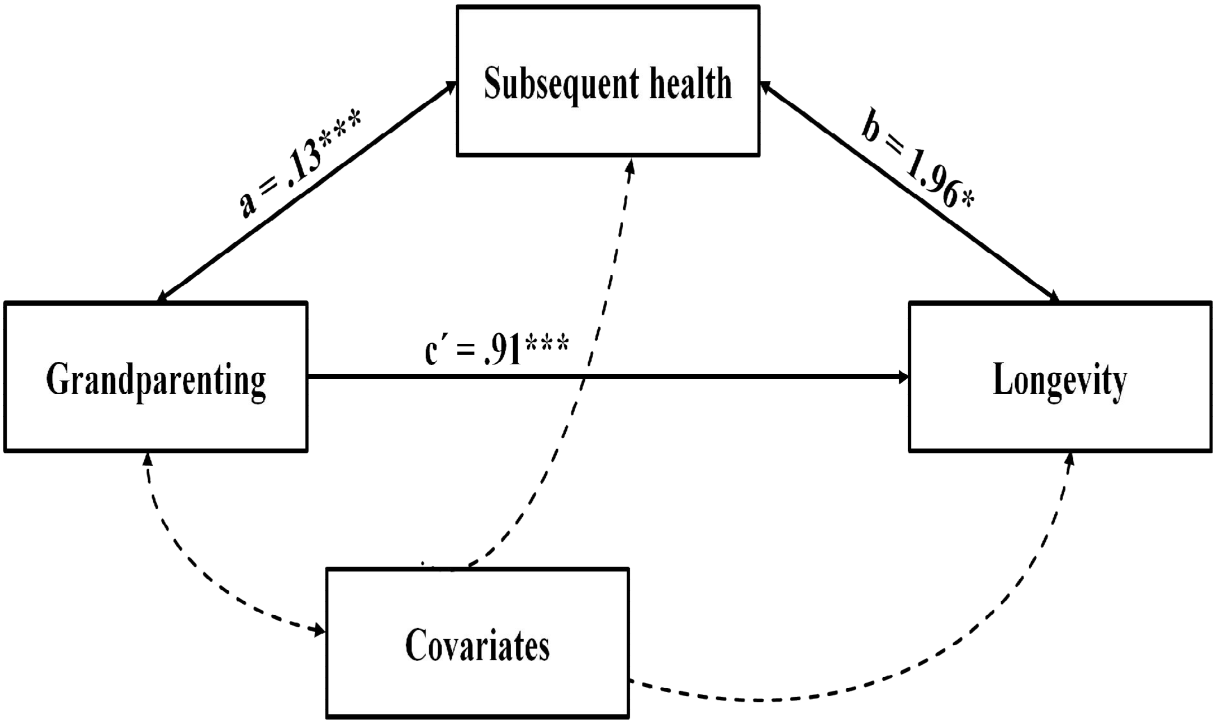
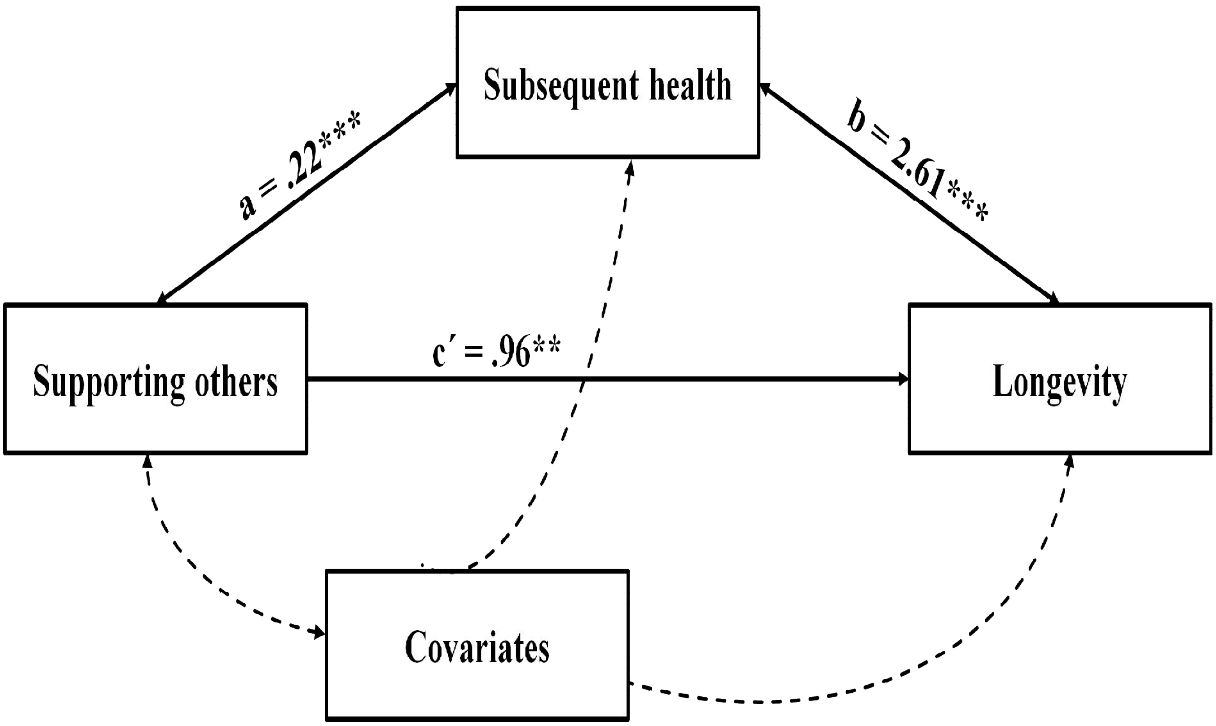


Figure S6. Regression coefficients from mediation model 1 testing indirect (ab) and direct effects (c′) of grandparenting on longevity (including the interaction term age × health), adjusted for covariates. Note * $p < .05$, *** $p < .001$.



Figures S7. Regression coefficients from mediation model 2 testing indirect (ab) and direct effects (c′) of supporting others on longevity (including the interaction term age × health), adjusted for covariates. Note ** $p < .01$, *** $p < .001$

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5.4 Appendix D: Manuscript 4

A New Niche?
The Theory of Grandfather Involvement

David A. Coall[1,2], Sonja Hilbrand[3,4], Rebbecca Sear[5], Ralph Hertwig[4]

[1] School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

[2] School of Psychiatry and Clinical Neurosciences, University of Western Australia, Crawley, WA, Australia

[3] Faculty of Psychology, University of Basel, Basel, Switzerland

[4] Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

[5] London School of Hygiene and Tropical Medicine, London, United Kingdom

Correspondence concerning this article should be addressed to David A. Coall, School of Medical and Health Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup, Western Australia 6027. Tel: +61 8 6304 2118; E-mail: d.coall@ecu.edu.au

Abstract

A multitude of factors influence the role a grandfather plays in his family. This chapter will present an interdisciplinary perspective of grandfathering incorporating research from the fields of evolutionary biology, sociology, economics and psychology. Examples will be used to show how these perspectives complement rather than compete with each other. A range of influences on grandfathering operating at the individual, familial and broader economic and cultural levels will be examined. Evidence points to grandfathering filling a new niche in modern societies: changing demographics mean there is greater need and opportunity for actively engaged grandfathers to help their families, especially in times of need. Recent empirical findings will be used to illustrate these points providing a basis for the more detailed information presented throughout the following chapters.

Key words: Grandfathers, interdisciplinary perspectives, grandfathering, grandparental investment, grandchild development

Introduction

Grandparents in contemporary industrialised societies invest substantial amounts of time, money and care in their grandchildren. For example, in the United States in 2007, 2.5 million grandparents were responsible for most of the basic needs of one or more of the grandchildren who lived in their household (U.S. Census Bureau 2009). Across 11 European countries, 44 per cent of grandparents report to have provided childcare for their grandchildren in the last 12 months without the parents present (Glaser et al. 2013). This involvement is considerable. With rapidly changing family structures and a concomitant change in the potential role of both grandmothers and grandfathers, research is now slowly moving from a strong focus on grandmothers to also understand the specific roles grandfathers play. It is naïve to lump all grandparents together in investigations, as is often done, or to focus only on maternal grandmothers or select the 'favourite' or most involved grandparent. This 'favouritism' in past research has resulted in the role of grandfathers being marginalized (Mann 2007), even the exclusion of grandfathers from research (Reitzes & Mutran 2004), and 'grandparent' becoming synonymous with 'grandmother' (Harper 2005). We aim to make first steps in addressing this blind spot in theory and research. We do so by bringing together research from evolutionary biology, sociology, economics and psychology to suggest an interdisciplinary perspective on grandfathering.

Across industrialised nations, grandfathers make notable contributions to grandchild care that come near to those made by grandmothers. In a sample of more than 35,000 people across ten European countries, 58 per cent of grandmothers and 49 per cent of grandfathers provided some care for their grandchild during a 12 month period (Hank & Buber 2009). A sample of Germans aged 55 to 69 years was observed to spend, on average, 12.8 hours each month supervising their grandchildren (Kohli et al. 2000). Like the investments of grandmothers, this notable investment of grandfathers has the potential to influence family function and grandchild health and well-being. At the same time, systematic differences between grandfathers and grandmothers are likely to influence grandfathers' involvement, the role they play and the consequences their behaviour exacts. Such differences concern timing of marriage, family formation, health and life expectancy, financial and social resources, life experiences and socialisation (Szinovacz 1998a; Tran et al. 2009). Next, we examine grandfathers' care using the main theoretical perspectives. Then we use the empirical example of sex and lineage to show how the diverse theoretical perspectives, often seen as conflicting, can complement each other. Finally, we explore the new niche that grandfathers may occupy in families as a result of demographic and family structure changes.

Why do grandfathers care?

Many grandfathers, in the immediate pre-grandparenthood stage, openly say to their family and friends that they do not understand what all of the fuss around becoming a grandparent is. Then, quite suddenly, with the arrival of their grandchild, there is a recognisable shift in grandfathers' views often with an immediate connection and an element of surprise (St George & Fletcher 2014). As we will discuss below, why this change takes place and why grandfathers invest in their grandchildren can be explored from many perspectives.

There are myriad dimensions that influence the role and impact grandparents have within families. These dimensions have been explored and documented by disciplines as diverse as sociology, economics, psychology, and evolutionary biology (Coall & Hertwig 2010). Each of these disciplines has made substantial contributions crucial to understanding the role of grandparents. To date, each discipline, however, has worked largely in isolation with little reference to, and benefit from, each other (Coall & Hertwig 2011). To achieve the greatest impact in this research area, it is time to join forces, by simultaneously exploring grandparental investment on multiple levels. Next, we briefly turn to some of the basic theoretical approaches (for detailed reviews, see Coall & Hertwig 2010).

The evolutionary perspective

The broadest level of explanation highlights humans within an evolutionary context as cooperative breeders. According to the cooperative breeding hypothesis, a mother does not raise her children by herself but is helped by other members of her social group (Hrdy 2009). Although in both traditional societies (generally low income, higher fertility, higher mortality with limited access to medical services) and contemporary industrialised societies (generally high income, low fertility, low mortality, access to medical services, and many would be considered post-industrial) these helpers are not necessarily kin (Coall et al. 2014; Ivey 2000). However, one class of kin helper, often available and inclined to help, is that of the post-reproductive adults — grandparents.

Within the predominantly anthropological literature, the focus has been on grandmothers. Williams (1957) initially proposed that menopause in humans was unique amongst animal species, and therefore, may benefit from an evolutionary understanding. He suggested menopause has evolved because, at a certain age, the benefit of continued care to existing children (and grandchildren) outweighs the cost of further reproduction (mainly risks associated with childbirth). This thesis triggered numerous investigations into the influences of kin in general — and grandmothers in particular — on the survival of offspring in contemporary traditional and historical human populations.

One of the resultant lines of research has culminated in the grandmother hypothesis. The grandmother hypothesis proposes that grandmothers might have been the most knowledgeable, efficient, and motivated helpers for reproducing mothers throughout human history (Hawkes, O'Connell, Blurton Jones, Alvarez & Charnov 1998). They are considered by some to be the mothers' ace in the hole (Hrdy 2009), helping them to leave more children and grandchildren than mothers whose own mothers are no longer available to help.

The grandmother hypothesis is currently the most influential theory to explain why human female longevity extends beyond menopause and the extended human lifespan more generally. In their now classic study of the influence family members have on child survival, Sear & Mace (2008) reviewed 45 studies investigating effects of the presence versus absence of various kin. Their findings generally support the beneficial influence of post-reproductive relatives, especially the maternal grandmother, in natural-fertility societies (these are generally high-fertility, high-mortality, societies in which contraceptives are not used). Of the 13 studies examining the influence of maternal grandmothers, nine (69 per cent) found that the presence of a maternal grandmother was associated with an increase in her grandchildren's probability of surviving the high-risk times of infancy and childhood. Studies have been more inconsistent in their findings about the benefits of paternal grandmothers: Depending on the investigation, having a paternal grandmother present had a positive (53 per cent), negative (12 per cent) or no (35 per cent) influence on child survival. Thus, although there is evidence in support of the grandmother hypothesis, it is not uniformly positive.

Is there evidence that a similar advantage of grandfathering might have influenced the evolution of the human life cycle? Sear & Mace (2008) found evidence that the presence of grandfathers painted a different picture compared to grandmothers. In 83 per cent (10 of 12 studies) of cases, the presence of maternal grandfathers was not associated with child survival, but in the remaining 2 studies it had a positive association. In the case of paternal grandfathers, 50 per cent of studies had no effect (6 of 12 studies), 25 per cent had a positive effect and the remaining 25 per cent showed that the presence of the paternal grandfather was associated with reduced child survival.

To date, there does not seem to be strong evidence that caring by grandfathers provides an adaptive explanation for why grandparents exist, in the same way that caring by grandmothers may explain the evolution of post-reproductive women (often grandmothers). In a historical Finnish population (1714-1839), with a positive influence of grandmothers' presence on child survival (Lahdenperä et al. 2004), no association was found between grandfathers' presence and increased grandchild survival. Furthermore, no evidence was found that grandfathers who lived longer ultimately had more grandchildren (see Lahdenperä et al. 2007 & 2011). Males could remarry after being widowed (divorce was not permitted in this historical population), and thus could reproduce for a longer period of time. Yet, among men who remarried, the channelling of resources to their new family had such a large impact on the survival of children from the man's original family that the number of grandchildren they had actually fell after 50 years of age (Lahdenperä et al. 2011). Reductions in paternal investment are also seen in serially remarried families in industrialised nations (Tanskanen, Danielsbacka & Rotkirch 2014). These first findings provide little reason to assume that grandfathering would have been favoured by natural selection. This research, however, is still in its infancy, and they do not yet preclude benefits of grandfathering at the family and individual level. We will see this shortly.

The economic perspective

Intergenerational transfers can take many forms. They can be via inheritance, they can consist of financial or time transfers, and transfers can be upward or downward. Possibly because of this variety, there is no overarching economic model of parental, let alone grandparental, investment. Nevertheless, most models rest on the utility maximization and rational choice framework, and many models of intergenerational transfers between family members have proposed the existence of two competing motives: altruism and self-interested exchange.

Children are expensive (Kaplan 1994), so why do parents shift so many of their resources to their children? According to Becker (1974) and Barro (1974), a parent's welfare is partly a function of the welfare of their children and grandchildren. Specifically, the parent's utility function incorporates the child's likely lifetime utility. This would explain why parents shift resources to their children as a function of those children's quality (e.g., skills and abilities) and later use wealth transfers to equalize outcomes across children (redistributive neutrality). Successive generations are thus linked by recursive altruistic preferences. That is, parents care altruistically for their children, who then transfer resources to their children, and so on.

In the self-interested exchange view, parents' transfers are part of a strategic bargaining between parents and children (see Laferrère & Wolff 2006). Intergenerational transfers can be understood as an investment through which parents try to secure their children's commitment in the future. Anticipating that when they become frail they will need help, parents invest now (e.g., education expenses, gifts, loans) and in the future (promise of inheritance) to increase the likelihood that their children will help them in their time of need.

There are a number of empirical challenges to both the altruistic and the self-interested exchange views (see Arrondel & Masson 2006). One problem for the altruistic view, for example, is that parents transfer most of their wealth through bequests, rather than earlier in the form of gifts, when children need them most. The self-interested exchange view faces the problem that although grandparents undoubtedly do invest substantial amounts of resources in their grandchildren, there is little evidence that grandchildren consistently reciprocate. The few grandparents who do receive support from their grandchildren may derive a relatively larger benefit, but such cases represent a small minority (Hoff 2007).

The sociological perspective

The extended family first received scant attention within the sociological modernisation paradigm and its emphasis on the nuclear family. In the last decades, demographic dynamics and the increasing fragility of state-funded pension schemes pushed the issues of intergenerational exchanges and intergenerational solidarity to centre stage. In studying these issues, sociologists have been predominately focused on structural factors (e.g., female participation in the labour force), social institutions (e.g., how wealth is taxed at death), and cultural values (e.g., family obligations and roles). Their investigations have produced a wealth of information on factors that clearly have consequences for patterns of grandparental investment but are consistently neglected by other fields (e.g., individual values and cultural norms). The potential value of this research building a coherent picture of grandparenting has been limited because, currently, these diverse studies are not situated within an overarching theoretical framework, the lack of which is recognized by sociologists to limit progress (Szinovacz 1998b).

One attempt toward creating an encompassing framework is the rational-grandparent model (Friedman, Hechter & Kreager 2008). Echoing the self-interested-exchange view in economics, this model assumes that the driving force behind investments is grandparents' concern about how they will be provided for in old age. To reduce this uncertainty, grandparents preferentially invest in those grandchildren whose parents are most likely to reciprocate in the future. Although some explicit predictions of the model (e.g., that grandparents are indifferent to biological relatedness) conflict with evolutionary perspectives, the benefit of this model is that it provides a framework of testable predictions about how grandparental investment varies.

Explaining the same robust grandparental Investment pattern from different perspectives

As emphasised before, treating all grandparents, or even all grandfathers, as a homogeneous group is remiss. It neglects the enormous variability among grandparents and the variable circumstances under which they contribute to their families. Across disciplines and measures of grandparental care, support and closeness, perhaps, the most robust pattern found in industrialised nations is this: Maternal grandmothers invest the most in their grandchildren, followed by maternal grandfathers, then paternal grandmothers, with paternal grandfathers investing the least (see Dubas 2001; Eisenberg 1988; Euler & Weitzel 1996; Hoffman 1980; Laham et al. 2005; Monserud 2008; Pollet et al. 2009; Uhlenberg & Hammill 1998). Across disciplines, however, different explanations for this pattern exist. Sociological theorizing holds that women are kin-keepers, tasked with holding kin groups together (Dubas 2001; Eisenberg 1988; Hagestad 1986). Similarly, according to the sociological family systems theory, it is the gatekeeper role of the parent (middle) generation that encourages (or not) the grandparent–grandchild relationship (Chan & Elder 2000; Rossi & Rossi 1990). Consequently, when grandparent and parent are female (e.g., maternal grandmother), the bond between grandparent and grandchild will be stronger relative to both parties being male (e.g., paternal grandfather). This combination of social factors can produce the grandparental investment pattern described above.

Evolutionary perspectives attribute this association between grandparent type and involvement (discriminative grandparental solicitude [Euler & Weitzel 1996]) to sex-specific reproductive strategies and paternity uncertainty (see Table 1 in Coall & Hertwig 2010). The term ’investment’ is here used to denote all resources, care and time that a grandparent provides to a grandchild. Purely because grandfathers are related to their grandchildren, evolutionary theory does not predict grandfathers will invariably help their grandchildren. Rather, according to Hamilton’s rule (Hamilton 1964), helping is moderated by opportunity costs that may differ across types of grandparents (e.g., grandmother vs. grandfather) making some investment alternatives more valuable than others.

Theoretically, paternity uncertainty is also predicted to play a role. Whereas women are 100 per cent certain who their children are, males cannot be 100 per cent certain that they are the biological father of their children. Note that the use of the word ‘certain’ in this context does not necessarily imply conscious thoughts and reflections. Grandparents with higher levels of certainty of their biological relationship to their grandchildren are assumed to invest more than those with lower levels of certainty. This assumption can explain why maternal grandmothers, certain of their relationships with their daughters and their daughters’ relationship with their grandchildren, invest more than paternal grandfathers. Paternal grandfathers have two points of uncertainty between themselves and their grandchildren, they cannot be 100 per cent certain of their relationship with their sons nor of their sons’ relationship with their grandchildren (see

Euler & Weitzel 1996; Smith 1987). The fact that these patterns of grandparental investment may be confined to industrialised societies and are not always present in rural (Pashos 2000; Kaptijn et al. 2013) and more traditional populations (Snopkowski & Sear 2015) means there is some question over the actual impact of paternity uncertainty (see Sear, in press) — also in light of the fact that cross-cultural estimates suggest only around 2 per cent of children are being fathered by someone other than their putative father (Anderson 2006).

The notion of paternity uncertainty suggests that maternal grandfathers and paternal grandmothers both would invest an intermediate amount, because they both have one point at which their relationship certainty with their grandchildren could be severed. In reality, however, maternal grandfathers invest significantly more than paternal grandmothers, for instance, in terms of frequency of face-to-face interactions and emotional closeness (Hoffman 1980). Several authors have addressed this limitation of paternity certainty by incorporating sex-specific reproductive strategies into their models of grandparental investment (Euler & Weitzel 1996; Huber & Breedlove 2007). Specifically, individuals are assumed to be more inclined to invest in female relatives than male relatives because investment put into female kin is more likely to be transformed into parental care, whereas resources invested into male kin may be used also for mating effort. Based on this logic, the higher investments of maternal grandfathers can be explained thus: They invest in their daughter's children relative to paternal grandmothers who invest in their son's children (Euler & Weitzel 1996). Thus, the combination of paternity uncertainty and sex-specific reproductive strategies predicts the often-found pattern of grandparental investment.

Finally, from a psychological perspective, it has been proposed that the robust grandparental investment pattern may result from the well-known differences in age and life expectancy between grandparent types (Tran et al. 2009). In a couple the male is often older, marrying later and having children later. In turn, their male offspring may also marry later. Thus, investment patterns may not be due to evolutionary or sociological explanations, but purely the result of grandfathers being older and potentially less healthy. The strength of an interdisciplinary perspective is illustrated here as these different fields of research have made, largely independently (see Coall & Herwig 2011), similar and broadly compatible predictions (Dubas 2001; Huber & Breedlove 2007) even though they focus on different levels of explanation (i.e., mechanistic versus adaptationist).

Complementary not competing approaches

Perhaps the key variable considered in the evolutionary grandparental investment literature is biological relatedness. Evidence is emerging that the genetic relationship between grandparents and grandchildren is an independent predictor of high grandparental investment, even in contemporary European societies (Coall, Hilbrand & Hertwig 2014). The impact of biological relatedness is often seen as incompatible with sociological and economic models of parental and grandparental investment. These models often assume investment to flow to those grandchildren (and their parents) who are more likely to reciprocate in times of need. If, however, non-biologically related individuals are less likely to reciprocate, which an evolutionary perspective would suggest, findings concerning the importance of biological relatedness will simultaneously support the predictions of the sociological, economic, and evolutionary accounts.

Reciprocal altruism, often conceptualized as exchanges between unrelated individuals, is likely to have originally evolved in genetically related kin groups. The psychological traits that maintain a system of reciprocity in humans (e.g., guilt, trust, sympathy, gratitude [Trivers 1971]) are likely to be stronger between close kin, which in-turn promotes close kin as less risky partners with whom to reciprocate (Allen-Arave, Gurven & Hill 2008). A strong attachment between parent and child has been proposed as a proximate mechanism for parents to identify and favour caring for their biological children (Daly & Wilson 1980). A similarly strong attachment relationship may also be found when parents adopt a young child (Hrdy 1999). Similarly, quality grandparent-grandchild attachment relationships may provide a crucial proximate mechanism whereby grandparents identify and preferentially care for grandchildren of their own children (Euler & Weitzel 1996; Kennedy 1990). Indeed, the many non-biological grandparents who do invest in step-grandchildren may do so because of particularly harmonious relationships between family members. Conversley, in some cases biological grandparents may not invest due to poor intergenerational relationships (Coall, Hilbrand & Hertwig 2014). Therefore, on balance, it is likely that investment in biological grandchildren improves inclusive fitness and is simultaneously more likely to be reciprocated. Consequently, our finding that high levels of investment are more likely to come from biological grandparents is not necessarily at odds with economic or sociological accounts of grandparental investment (see also Tanskanen, Danielsbacka & Rotkirch 2014).

Family size, birth order and availability of other kin influence grandfathering

There are various factors that are likely to influence investment by grandfathers and grandmothers and, yet, they are not currently included in most analyses. The preponderance of the nuclear family in industrialised nations means concomitant changes in family size, birth order and availability of other kin. In traditional societies, larger families can recruit older siblings to provide resources for a family (Ivey 2000; Kramer 2002). In industrialised societies, in contrast, the impact of sibling help for child care is likely to be low because siblings are so closely spaced (Sear & Coall 2011). However, in both cases, a larger family size, ceteris paribus, dilutes the resources available for each child (Blake 1987; Hertwig et al. 2002; Marks 2006) and grandchild (Coall et al. 2009; Leonetti et al. 2005; Uhlenberg & Hammill 1998).

Larger family sizes offer more investment options and invite preferential investment. In a study of 787 Australian university students, Laham et al. (2005) observed that the emotional bond grandchildren reported to their maternal grandfather or paternal grandmother depended on the availability of other kin. Moreover, the general finding that maternal grandfathers provide more investment to grandchildren than do paternal grandmothers only held when the paternal grandmothers had other children in whom to invest. This means that if a grandmother has both a son and a daughter, she tends to focus on her role as a maternal rather than a paternal grandmother. These findings extend to grandfathers as well. Using the Survey of Heath Ageing and Retirement across Europe data, Danielsbacka, Tanskanen, Jokela & Rotkirch (2011) found that when grandfathers had grandchildren via both a son and a daughter, they provided more child care to their daughter's children (maternal grandfather) rather than their son's children (paternal grandfather).

Do modern grandfathers fill a novel niche?

There is no doubt that the role of grandfathers is work in progress. It will continue to evolve through time as social factors that influence it change (see also Chapter 3). To extend this timeframe further, here, we briefly consider traditional and contemporary industrialised societies. As was detailed above, evidence from traditional societies show the fathers and grandfathers appear to have a smaller impact on child survival than mothers and grandmothers (Sear & Mace 2008). This may be explained by the fact that women universally invest more in both parenting and grandparenting effort than men, at least in terms of direct childcare (see Kokko & Jennions 2008 for evolutionary explanations of why mothers tend to care more than fathers). Human males, more so than most other mammals, frequently invest heavily in parental effort. This investment can nevertheless vary quite substantially between men both within and between societies, as some men derive greater fitness benefits from investing more in mating rather than parenting effort. Similarly, the role of grandfathers may be more variable than that of grandmothers. There are some environments in which older men may still benefit from continued investment in mating, acquiring a new spouse for example, but other environments exist where it may pay older men to invest in parenting or grandparenting effort.

A look at the empirical evidence confirms that the role of grandfathers is highly variable and contingent on the environment. For example, in those hunter-gatherer and horticulturist societies where the male contribution to subsistence is substantial, men can continue to provision their families into older age, so that grandfathers may provide valuable nutritional resources (Hooper, Gurven, Winking & Kaplan 2015; Kaplan 1994). In other societies, however, such as those agricultural societies where polygyny or serial monogamy is common, a high-ranking man may reserve the most valuable resources for himself and redistribute them elsewhere for other advantage such as increased mating opportunities. This heightens competition for resources within the family, and may explain those findings where a negative impact on grandchild survival has been found (Campbell & Lee 1996; Kemkes-Grottenthaler 2005).

Overall, the large literature concerning the involvement of fathers and their impact on child wellbeing suggests that fathers may be more consistently available, if not more important, in contemporary industrial than traditional societies (see Amato and Rivera 1999; Lamb 2010; Sigle-Rushton and McLanahan 2004). One may thus hypothesize that grandfathers also fill new niches in families that may have appeared as investment in children has increased and family structures have changed. The role of the 'competent provider' mentioned above in traditional societies may have diminished substantially in societies with small families and few children. However, it is being replaced with a more engaged grandpaternal role (Roberto, Allen & Blieszner 2001). It is clear the roles of fathers and more pertinently, grandfathers have changed dramatically in contemporary developed societies (Sear & Coall 2011).

Among other roles grandmothers play, they are seen to fill a void that opens up when fathers are absent due to death, divorce or hunting (Konner 2010; Marlowe 2005; Scelza 2009). Consistent with this substitution role, it has been found that single-parent families in traditional populations actually have more helpers than dual parent families (Sugiyama & Chacon 2005). The normative nuclear family system in contemporary industrialised societies means that men (both fathers and grandfathers) may benefit the family by invesing more in parenting and grandparenting.

The ever increasing investment in children in contemporary industrialised societies means nuclear families require heavy investment from vertical kin in the absence of support from broad, horizontal kin networks. This also restricts men's mating opportunities given that polygyny is not permissible and serial monogamy comes with high costs of investing in multiple families. Further, with the advent of social security systems, after retirement, grandfather availability has potentially increased, especially for the investment of time, such as childcare. Therefore, as fathering has, grandfathering may now become a more important resource for the family, providing grandfathers with the opportunity to carve out their own new niche.

Consistent with this high-investment niche, research literature shows that grandfathers are becoming actively involved, engaged and make a difference to their grandchildren. Crucially, this is movement away from the traditional view of grandfathers as passive, remote and disengaged (Roberto et al. 2001). Tinsley and Parke (1987) investigated measures of physical and mental development as a function of the frequency of grandparent–grandchild contact with seven-month-old infants and their families. Each grandparent was observed playing with the infant, in the infant's house, for five minutes and the interaction was assessed throughout. Grandfathers who were rated as highly responsive and highly playful had infants with higher Bayley Scales of Infant Development raw and adjusted Physical Health Index scores (Tinsley & Parke 1987). Although engaging play may be a universally positive influence, other outcomes such as education may be more nuanced. Scholl Perry (1996) investigated the influence of grandparental investment on academic achievement and found the social distance to grandfathers, but not grandmothers, was associated with grade point average. Specifically, a larger social distance between the student and their paternal grandfather was associated with a higher grade point average. Conversely, a smaller social distance to maternal grandfathers was associated with higher grade point averages. The scarcity of this evidence highlights the need for further investigation into the emerging role grandfathers are playing.

There is also reason to speculate that the availability of the grandfather niche may not be equally distributed across demographic groups. Lower socio-economic groups experience higher rates of single motherhood, less father involvement (Nettle 2008), more reliance on kin other than the father (Thomese & Liefbroer 2013), and receive less paid child care. Therefore, through choice or necessity, this new grandfather niche may be more common in lower socio-economic areas.

Grandfather niche: Single teenage mother families

We have suggested that grandfathers have found a new niche, which may be especially prominent in low-resource family environments such as single-parent families and families experiencing poverty. For example, in studies that explicitly focus on single-parent families, a resident grandfather can have a significant influence on grandchild development. In a study of 66 multi-generational, teen-mother families in Detroit (US) — with the biological father absent, and grandchildren between one and two years of age — higher levels of grandfather nurturance were associated with the child being more likely to comply with its mother's requests. Moreover, higher levels of grandfather involvement substantially reduced negative affect in the grandchildren. This effect was robust and remained after adjustment for socio-economic status, grandmother's occupation, hours of grandmother employment, grandfather's age, and hours of grandfather employment (Oyserman, Radin & Benn 1993; Radin, Oyserman & Benn 1991). Interestingly, there was no evidence of grandmother effects in this sample. It may be the case that in these father-absent, single-mother, multigenerational households, the grandfather assumes the father figure role thus overshadowing the grandmother role. It also demonstrates that grandfathers are rising to the challenges associated with difficult low-resource family environments (Roberto et al. 2001). Potentially, this role may represent an emerging niche for grandfathers that traditionally might have been the domain of the maternal grandmother.

The evidence that the influence a grandparent has during times of need is larger has been established. However, the question of whether grandparents intentionally direct their resources where the need is greatest has received less attention. Need is an important new variable that is emerging in the grandparental investment literature (Roberto et al. 2001; Snopkowski & Sear 2015; Thomese & Liefbroer 2013). It is also a variable that is not entirely dealt with by the predominant, utility based models detailed above and is likely to benefit from consideration of evolutionary perspectives (Hooper, Gurven, Winking & Kaplan 2015). Need and responding to need is likely to be important in single-parent family and step-families that are often resource poor especially in terms of social capital (see Sear & Coall 2011).

Step-grandfather niche: Increasing prevalence

With increased rates of divorce and remarriage in industrialised societies, the changing roles of grandparents may be most salient for grandfathers. Falling rates of marriage and high rates of divorce and remarriage cause the proportion of non-kin, including grandparents, in any family to increase. In 2009, for instance, the U.S. marriage rate was 6.8 per 1,000 people with a divorce rate of 3.4 per 1,000 people (Tejada-Vera & Sutton 2010). After separation, 25 per cent of women, who are more likely to have custody of their children, will re-partner within two years and re-marry within five years (McNamee & Raley 2011). Therefore, males are increasingly likely to marry into existing families, forming new families and becoming step-fathers and step-grandfathers.

Quality relationships between grandchildren and their biological grandparents across nuclear, step-parent, and single-parent families have been associated with improved emotional health of grandchildren (Ruiz & Silverstein 2007). Moreover, maintaining quality contact with paternal grandparents who are often alienated during re-marriage and step-family formation is beneficial to the behavioural adjustment and mental health of both grandparents and grandchildren (Attar-Schwartz et al. 2009; Bray & Berger 1990; Drew & Silverstein 2007). The role that non-biological grandparents (e.g., a step-father or the step-father's parents) play in childcare and grandchildren's development has, in contrast, received little attention. This, in turn, has resulted in calls to introduce genetic relatedness into interdisciplinary studies of grandparental investment (Danielsbacka, Tanskanen & Rotkirch 2015; Kaptijn et al. 2013). Using the Survey of Heath Ageing and Retirement across Europe, Coall and colleagues (2014) found that while biological grandparents were more likely to provide frequent informal childcare for their grandchildren, non-biological grandparents, who are typically step-grandparents, still invested in their grandchildren and were more likely to invest on a monthly basis or less frequently. Crucially for this chapter, non-biological grandparents were significantly more likely to be grandfathers. This study provides initial evidence that the role of step-grandparent is more likely to fall to grandfathers. At increasing rates in the future, grandfathers will experience this new and challenging role in step and blended families.

Summary of grandfather effects in industrialised societies

Like the role of fathers, in contrast to traditional societies, grandfathers in contemporary industrialised societies can have an equal if not larger impact on grandchild development than grandmothers. The effects grandparents have on grandchild development are generally of a small size, however, some of the biggest effects are found for grandfathers (see Radin et al. 1991). The fact that these associations are found across grandchild ages, study designs and diverse populations, and generally take into account a range of potential confounding variables adds strength to these findings. Although the direction of the causal association cannot be established from these studies, the ability in longitudinal studies to adjust for variables including earlier markers of grandchild development (e.g., Pittman 2007) suggests grandparents may have an actual causal impact. Moreover, like the compelling ethnographic data from traditional societies, these findings are supported by qualitative analyses that show it is not the grandparent-grandchild relationship per se that makes a difference, rather it is what grandparents actually do with their grandchildren that is crucial (see El Hassan Al Awad & Sonugabarke 1992; Botcheva & Feldman 2004; Griggs et al. 2010; Coall & Hertwig 2011). In contemporary industrialised societies the child outcomes of interest have changed, and studies are now exploring social well-being and cognitive development rather than child survival. However, the evidence that grandparents, including grandfathers, have a positive influence on grandchild development is growing. As is the evidence that grandfathers may be actively assuming new niches within families, especially in the trying times of divorce, re-marriage and economic hardship.

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