Abstract

The grandmother hypothesis states that menopause evolved in humans because, as women aged, the direct fitness benefits associated with the capacity to produce offspring were outweighed by the indirect fitness benefits associated with the provision of care to grandchildren and other kin. Drawing on the underlying life-history logic, it may be further hypothesized that—compared to pre-menopausal women—post-menopausal women will dedicate more temporal resources to kin care. This hypothesis was tested in two studies, on results obtained from two large datasets documenting altruistic behaviors of pre-menopausal and post-menopausal women in the United States (N=7,161) and Australia (N=25,066). Results from both studies revealed that (even when controlling statistically for age, health, financial resources, and other pertinent variables), postmenopausal women devoted more time to kin care. This effect was specific to kin care: Menopause status did not predict a measure of non-kin-directed altruism (time spent volunteering). These results provide the first empirical support for a previously-untested behavioral implication of the grandmother hypothesis.

Keywords: Grandmother hypothesis, Grandparental care; Kinship; Menopause

1. Introduction

Among humans, women's capacity to naturally produce offspring comes to an end with the onset of menopause, but they have the capacity to live for many decades longer—a life-history profile that is rare within the animal kingdom, even among primates (Alberts et al., 2013). The reason for menopause is not known, and several compatible evolutionary theories have been proposed. One explanation for the evolution of menopause and a long post-reproductive life-span is provided by the *grandmother hypothesis* (Hawkes & Coxworth, 2013; Hill & Hurtado, 1991).

This hypothesis was articulated as early as 1957, when George Williams observed that, although menopause may represent the end of childbearing potential, it need not represent the end of reproductive activity:

> "As long as postmenopausal women contribute to the welfare of their kin, they affect the successful reproduction of their genes. Williams hypothesized that menopause evolved when other changes in our lineage made late births riskier and infants more dependent. Older mothers would be more likely to die in childbirth, leaving orphans unable to survive without them. He surmised that these circumstances would favor tendencies to stop fertility early and for mothers to invest more in previously born offspring than in risky new ones." (Hawkes & Coxworth, 2013, p. 294)

This line of reasoning is exemplified by a post-menopausal grandmother who provides care to her grandchildren. This grandparental investment increases the likelihood that her grandchildren will survive to reproductive age (and also may increase the likelihood that her

children will produce additional grandchildren), thus enhancing the grandmother's own reproductive fitness. It is this line of reasoning that provides an explanation for the evolutionary origins of menopause and postmenopausal longevity and has come to be known as the grandmother hypothesis (Hawkes & Coxworth, 2013).

In order for the grandmother hypothesis to provide a persuasive explanation for menopause, there must be behavioral evidence that post-menopausal grandmothers provide resources to their offspring (and other kin), and that these resources have beneficial reproductive outcomes. Empirical evidence shows that grandmothers do contribute food and other valuable forms of assistance (Hawkes, O'Connell & Jones, 1989), and that the presence of grandparents—and thus the opportunity for grandparental care—is positively associated with descendants' reproductive fitness (Fox et al., 2010; Sear and Mace, 2008; Sear, Mace & McGregor, 2000). For example, historical data from pre-modern populations in Canada and Finland indicate that the presence of a living post-reproductive grandmother was associated with a greater number of grandchildren produced by that grandmother's sons and daughters, and with a greater number of these grandchildren surviving into adulthood (Lahdenperä, Lummaa, Helle, Tremblay & Russell, 2004). Another study in rural Gambia directly compared the presence of pre- and post-menopausal grandmothers, and found that the presence of a post-menopausal grandmother was associated with improved grandchild nutrition (Sear, Mace & McGregor, 2000). These and other results (e.g., Schwarz et al., 2016; for a review, see Hawkes & Coxworth, 2013) attest to the plausibility of the grandmother hypothesis as an evolutionary explanation for a human life-history characterized by both menopause and post-reproductive longevity.

If indeed the grandmother hypothesis is correct, one implication is that, compared to the pre-menopausal phase of the adult female lifespan, the post-menopausal phase may be accompanied by an increase in kin-directed altruism. This implication emerges from life-history principles that underlie the grandmother hypothesis. According to life history theory, organisms' developmental trajectories and behavioral strategies are characterized by trade-offs—including a fundamental trade-off between mating effort and parenting effort (Del Giudice, Gangestad, & Kaplan, 2016). When resources are invested in the production of new offspring, those resources are unavailable for the provision for parental care to existing offspring. Reciprocally, when resources are withdrawn from the production of new offspring, those resources may be invested in parental (and grandparental) care instead. Following menopause, newly available metabolic resources—which previously were consumed by maintenance of female reproductive physiology—may instead be directed to other physiological mechanisms, including mechanisms that regulate care-giving behavior (Rilling, 2013). Other kinds of resources may also be reallocated among post-menopausal women. For example, temporal resources may be strategically directed away from behaviors associated with mating, and instead allocated toward behaviors associated with parental (and grandparental) caregiving.

This conceptual analysis suggests the following hypothesis: Compared to pre-menopausal women, post-menopausal women may engage in a higher level of caregiving behavior directed toward grandchildren and other kin. To our knowledge, this hypothesis has not previously been tested against empirical evidence. The two studies reported here provide such a test.

In addition to testing this hypothesis, these studies also test whether the hypothesized relation between menopause and altruistic behavior—if it occurs at all—is specific to kin care. If there is a post-menopausal increase in kin-directed altruism, this increase might plausibly reflect a more general increase in altruistic behavior (due, for instance, to the increased availability of temporal resources that, prior to menopause, had been allocated to other activities). If so, then this increase may not be specific to kin care, and would instead manifest in a wide range of altruistic behaviors (e.g., volunteerism). But, if a post-menopausal increase in kin-directed altruism reflects a behavioral adaptation that evolved specifically because of its indirect fitness implications (as specified by the grandmother hypothesis), then this increase in altruistic behavior may be specific to kin care. The two studies reported below include analyses designed to distinguish between these two possibilities.

We conducted analyses on two datasets produced by two different large-scale health assessment research projects: The U.S. Health and Retirement Study (HRS; Study 1), and the Australian Longitudinal Study on Women's Health (ALSWH; Study 2). These datasets provide information on female participant's menopause status and on time devoted to altruistic activities (including grandparental care-giving and volunteering). They also include a variety of control variables that might plausibly correlate with both menopause and altruistic behavior, such as age (which was an essential covariate in all analyses because of its strong relationship with menopause status), health, and the availability of resources. Because of differences in the methodologies employed by the HRS and ALSWH projects, Study 1 focuses exclusively on grandmothers, whereas Study 2 includes a wider range of pre- and post-menopausal women (not just grandmothers). Also, whereas the HRS (Study 1) dataset allows for examination of the amount of time that pre- and post-menopausal grandmothers spent caring specifically for

their grandchildren, the ALSWH (Study 2) dataset did not include any item that was specific to grandchildren; consequently, Study 2 assessed differences in the amount of time that pre- and post-menopausal women spent voluntarily caring for children more generally (either their own grandchildren or other people's children). In both studies we compared pre- and post-menopausal women at each specific year for which relevant data were available, and also utilized multilevel modeling to combine data across years (thus increasing statistical power).

2. Study 1

Data were obtained from the Health and Retirement Study (HRS), a publically available study of health and aging in the United States (http://hrsonline.isr.umich.edu; RAND version data files were used). The HRS has been collecting data every two years since 1992. Approximately 20,000 Americans have participated in the HRS, and they form a representative sample of the U.S. population. Female participants' menopause status was not measured prior to 2008; and data collected in the most recent available year (2014) included only 14 women—all of whom were post-menopausal—who fit the inclusion criteria identified below. Therefore, we conducted analyses on data obtained in 2008, 2010, and 2012.

2.1. Methods

2.1.1. Participants

Data from HRS participants were included in analyses if these data identified the participant as female, a grandparent, either pre- or post-menopausal, and between the ages of 30-80. (Four "grandmothers" indicated that they were under 30 years of age; these responses were suspected to represent data entry errors and were excluded. Participants over 80 were excluded in order to reduce the prevalence of health problems that could impede the ability to provide childcare.) Additionally, HRS participants' data were included only if their responses

provided useful information on time spent caring for grandchildren. (E.g., 651 HRS

participants replied that they provided more than 0 hours of care, but did not report additional

information that would allow their responses to fit the coding scheme described below; data

from these participants were excluded). Based on these inclusion criteria, we conducted

analyses on a total of 7,161 observations across all three time points (2008, 2010, and 2012).

These data were provided by 4,700 discrete individuals (2,240 provided responses at one time

point, 2,459 at two time points, and 1 at all three time points). For additional information on

participants, see Supplementary Materials, Table S1.

2.1.2 Variables of Primary Conceptual Interest

Menopause status. Menopause status was determined based on responses to two

questions. If participants provided the age at which they "finished going through menopause",

they were categorized as post-menopause. Some participants did not provide an age in

response to that question, but did respond to the question "Regarding menopause, do you think

you are without a sign, just beginning, in the middle, near the end, or all through?" Participants

were categorized as post-menopause if they responded "all through," and as pre-menopause if

they responded "without a sign." Of the total of 7,161 observations across the three time

points, 266 were classified as pre-menopause and 6,895 as post-menopause.

Grandparental Caregiving. All participants were asked "Roughly how many hours

altogether did you, yourself, spend taking care of grand or great-grandchildren" in the past 2

years. Responses were either a specific estimate (1,159 observations), or an indication of

whether the total number of hours fell into one of four categories (6,002 observations). We

created a four-level variable corresponding to those 4 categories: 1 = 0 to 99 hours; 2 = 100 to

199 hours; 3 = 200 to 499 hours; 4 = 500 or more hours. Responses from all 7,161

observations—including exact estimates—were coded accordingly.

Volunteering. A subset of 6,682 observations (247 pre-menopausal, 6,435 post-

menopausal) provided an answer to the question "Have you spent any time in the past 12

months doing volunteer work for religious, educational, health-related or other charitable

organizations?" and, if so, were further prompted to indicate whether their total number of

volunteer hours fell into one of four categories. Responses were coded accordingly: 1 = 0 to 49

hours; 2 = 50 to 99 hours; 3 = 100 to 199 hours; 4 = 200 or more hours.

2.1.3. Control Variables

Any observed statistical relationship between menopause status and grandparental

caregiving has the potential to be misleading due to other variables that correlate with both

menopause status and grandparental caregiving. We employed two strategies to identify such

variables, in order to statistically control for them. One strategy drew upon previous research

pertaining to either menopause status or altruistic behavior; and, on the basis of further

conceptual analyses, we identified a set of variables that might plausibly be related to both

menopause status and grandparental caregiving. This strategy identified variables pertaining to

participant's age, health, access to resources, and number of grandchildren. The second

strategy was purely data-driven: focusing specifically on HRS data obtained in 2010 (the time

point with the largest sample of pre-menopausal grandmothers), we identified 1,049 variables

for which there were responses from a minimum of 250 total grandmothers and a minimum of

50 pre-menopausal and 50 post-menopausal grandmothers,[1] and then computed the zero-order

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[1] These criteria were set because estimates of correlation are often inaccurate in small samples (Schönbrodt & Perugini, 2013) and because—since fewer than 4% of participants were

correlation between each of those variables and both menopause status and grandparental caregiving. If the variable correlated with both menopause status and grandparental caregiving at a magnitude of at least $r = |.15|$, the variable was included as a control variable. Out of the 1,049 candidate variables, only 1 variable met this threshold: the year in which the participant began working in their current industry. Details on the full set of control variables included in our analyses are as follows:

Age. All 7,161 observations provided an age. (Combining across all three time points, correlations with menopause status and grandparental caregiving were $r = .41$ and $r = -.12$, respectively.)

Number of Grandchildren. All 7,161 observations provided total number of grandchildren as well as their total number of great-grandchildren. These two variables were summed to create a single variable. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = .07$ and $r = -.04$, respectively.)

Health. A subset of 7,157 observations (266 pre-menopausal, 6,891 post-menopausal) provided health ratings on a 5-point scale, with higher values representing better health. We employed this variable as a measure of *perceived health*. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = -.04$ and $r = .03$, respectively.) Additionally, a smaller subset of 1,805 observations (95 pre-menopausal, 1,710 post-menopausal) provided ratings (on 4-point scales) of hand strength, how often they became short of breath, and how often they had difficulty with balance. These values were standardized and the mean was computed to form an index of *physical functioning* (Cronbach's alpha =

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premenopausal—many variables with a minimum of 250 total responses had limited variability on the pre-menopause / post-menopause variable (i.e. all respondents were postmenopausal).

0.20), with higher values representing better health. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = -.10$ and $r = .05$, respectively.)

Temporal Resources. A subset of 998 observations (55 pre-menopausal, 943 post-menopausal) provided ratings on the extent to which their job impeded their ability to spend time with their family and friends. (Ratings were made on a 4-point scale; higher values represent increased impediment.) We employed this variable as a measure of *perceived time pressure*. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = .01$ and $r = -.01$, respectively.) Also, a subset of 2,658 observations (171 pre-menopausal, 2,487 post-menopausal) provided ratings on hours generally worked per week. We employed this *hours worked* variable as a separate indicator of participant's lack of temporal resources. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = -.07$ & $r = .02$, respectively.)

Financial Resources. A subset of 2,923 observations (81 pre-menopausal, 2,748 post-menopausal) provided ratings on satisfaction with financial situation, and difficulty meeting monthly payments (ratings were made on 5-point scales). After reverse-scoring the latter rating, the mean was computed to create an index of *perceived financial comfort* (Cronbach's alpha = 0.80), with higher values representing greater perceived comfort. (Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = .06$ and $r = -.06$, respectively.) Also, a subset of 2,148 observations (154 pre-menopausal, 1,994 post-menopausal) provided reports of their income during the previous year. Responses were log transformed to adjust for positive skew, to create a normally distributed measure of *income*.

(Combining across all 3 time points, correlations with menopause status and grandparental caregiving were $r = -.05$ and $r = -.02$, respectively.)

Year Entered Industry. A subset of 1,946 observations (141 pre-menopausal, 1,805 post-menopausal) identified the year in which they began working in the "type of work" that they were currently employed in. (For data collected in 2010, this variable correlated with both menopause and grandparental care at a level that exceeded $r = |.15|$; but, when combining across all 3 time points, these correlations were $r = -.14$ and $r = .00$, respectively.)

2.2. Results

2.2.1. Relation between Menopause Status and Grandparental Caregiving

In order to test the primary hypothesis, we conducted multiple, complementary, analyses. The first set of analyses tested the hypothesis separately on data obtained during each of the three time points (2008, 2010, and 2012). These analyses controlled for age (the one control variable that was substantially correlated with menopause and which was reported by all participants), but did not control for all control variables (because data on most control variables was available only for small subsets of participants, thus imposing severe constraints on sample size and statistical power). A second set of analyses employed hierarchical linear regression (HLM) to test the hypothesis on the full set of data combined across all three time points. These HLM analyses attended to all of the control variables identified above.

Table 1. *Cross Sectional Analysis of Grandparental caregiving reported by pre- and post-menopausal grandmothers in the U.S. Health and Retirement Study.*

Time Point	Pre-Menopausal Grandmothers		Post-Menopausal Grandmothers		Cohen's d	p
	n	M (SD)	n	M (SD)		
2008	55	1.35 (0.91)	3058	1.60 (1.06)	0.25	< .001
2010	115	1.56 (1.00)	665	1.65 (1.08)	0.09	.58
2012	96	1.47 (0.99)	3172	1.50 (1.00)	0.03	.001

Note: p-values from ANCOVA predicting grandparental caregiving from menopause status, while controlling for grandmother's age.

Table 1 reports the mean level of grandparental caregiving reported by pre- and post-menopausal grandmothers during each of the three time points in the dataset (2008, 2010, and 2012). For each of these time points, we conducted an analysis of covariance (ANCOVA) predicting grandparental caregiving from grandmother's menopause status, while controlling statistically for grandmother's age. Results revealed that, for all three time points, the mean level of grandparental caregiving was higher among post-menopausal women than pre-menopausal women; and for two of these time points—2008 and 2012—this mean difference was statistically significant, $p < .001$ (see Table 1).

Subsequent analyses were conducted on data combined across all three time points, using hierarchical linear modeling (HLM). These statistical analyses were conducted using R (R Core Team, 2012) and lme4 (Bates, Mächler, Bolker, & Walker, 2015).

First, we performed a linear mixed effects analysis of the relationship between menopause status and grandparental care, controlling for age. Repeated measures of menopause status (Level 1) were nested within individuals (Level 2). Within each participant, repeated measures of age at each time point was group mean centered and used as a level 1 predictor; in addition, a participant's average age across all time points was grand mean centered and used as a level 2 predictor (following advice from Enders & Tofighi, 2007). Menopause status was dummy coded (0=pre-menopause; 1=post-menopause), and used as a level 1 predictor. A random intercepts model was computed, employing the following equations:

Level 1: Grandparental Care$_{ti}$ $_{=}$ π_{0i} + π_{1i} (Menopause Status$_{ij}$) + π_{2i}(Age) + e_{ti}

Level 2: π_{0i} = β_{00} + β_{01} (Average Age) + r_{0i}

Results revealed that, controlling for age, menopause status was a significant predictor of grandparental caregiving (b=0.40, SE=0.07, p<.001).

Additional analyses were preformed to control for additional variables. Initially, in order to guard against data loss (because data on different control variables were available from different subsets of participants), each control variable was individually entered (along with age and menopause status) into an HLM model predicting grandparental caregiving. For these analyses, each variable was group mean centered and entered as a level one predictor, as well as averaged across the individual, grand mean centered, and entered as a level two predictor. For example, the HLM model including hours worked is displayed below:

Level 1: Grandparental Care$_{ti}$ $_{=}$ π_{0i} + π_{1i}(Menopause Status$_{ij}$) + π_{2i}(Age) + π_{3i}(Hours Worked) + e_{ti}

Level 2: π_{0i} = β_{00} + β_{01}(Average Age) + β_{02}(Average Hours Worked) + r_{0i}

Results revealed that, in each of these analyses, menopause status remained a significant predictor of grandparental caregiving (p's < .03; for detailed results see Supplementary Materials, Tables S3-S10). Across this set of analyses, the only statistically significant predictors of grandparental caregiving were: menopause status, age, average age, and average perceived health.

Based on these results, we preformed a final HLM model including all predictors that, in the preceding analyses, were revealed to be significant predictors of grandparental caregiving:

Level 1: Grandparental Caregiving$_{ti}$ = π_{0i} + π_{1i}(Menopause Status$_{ij}$) + π_{2i}(Age) + e_{ti}

Level 2: π_{0i} = β_{00} + β_{01}(Average Age) + β_{02}(Average Perceived Health) + r_{0i}

Results are presented in Table 2. These results show that, even when controlling for other variables that also predict grandparental caregiving (and, in the case of age, also correlate with menopause status), menopause status remained a statistically significant predictor of grandparental caregiving (b=0.40, SE=0.07, p < .001).

Table 2. *Results of HLM analysis on U.S. Health and Retirement Study dataset, predicting grandparental caregiving from menopause status, age, average age, and average perceived health.*

	Grandparental Caregiving Coefficient	SE	*p*
Intercept	1.17	.07	<.001
Menopause Status	0.40	.07	<.001
Age (Level 1)	-0.05	.01	<.001
Age (Level 2)	-0.02	<.00	<.001
Perceived Health (Level 2)	0.03	.01	.009

Note. Level 1 *n* = 7,157, Level 2 *n* = 4,698. Premenopause *n* = 266; Postmenopause *n* = 6,891. Menopause status coded as 0 = pre-menopause, 1 = post-menopause; ICC = 0.40; Deviance reduction = 160.78 and indicates significant deviance reduction from unspecified model deviance. HLM analysis employed full maximum likelihood estimation. Unstandardized regression coefficients are presented.

2.2.2. Relation between Menopause Status and Volunteering

In order to test whether menopause status also predicted volunteering, we conducted HLM analyses analogous to those reported above. One analysis predicted volunteering from menopause status and age:

Level 1: $\text{Volunteering}_{ti} = \pi_{0i} + \pi_{1i}(\text{Menopause Status}_{ij}) + \pi_{2i}(\text{Age}) + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + \beta_{01}(\text{Average Age}) + r_{0i}$

Results revealed no significant relation between menopause status and volunteering (b=-0.07, SE=0.06, p=.31). An additional analysis included all predictors identified in Table 2:

Level 1: $\text{Volunteering}_{ti} = \pi_{0i} + \pi_{1i}(\text{Menopause Status}_{ij}) + \pi_{2i}(\text{Age}) + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + \beta_{01}(\text{Average Age}) + \beta_{02}(\text{Average Perceived Health}) + r_{0i}$

Once again, there was no significant relation between menopause status and volunteering ($b=-0.03$, $SE=0.06$, $p=.68$).

2.3. Discussion

Results of Study 1 indicate that, compared to pre-menopausal grandmothers, post-menopausal grandmothers devoted more time to caring for grandchildren. This relationship persists even when controlling for a variety of potentially confounding variables. Additional results revealed that there was no analogous relation between menopause status and a different form of altruistic behavior (volunteering), suggesting that the observed effect on grandparental caregiving may be specific to kin-directed altruism.

Considered alone, these results must be interpreted with caution because of limitations to the HRS dataset that was used in Study 1. One limitation was that these data were obtained from residents of a single country. A second limitation pertains to sample size. Although the full sample of grandmothers was large ($N = 7,161$), only 266 of these grandmothers were pre-menopausal—and only 38 of them provided data on all control variables. More generally, data on different control variables was available only from different subsamples of participants. Given these limitations, it was not feasible to conduct analyses that simultaneously controlled for all of the additional variables identified that might plausibly be related to both menopausal status and kin care. Additionally, the HRS dataset included just 28 grandmothers who completed measures during both pre-menopause and post-menopause time points, rendering it impossible to conduct inferentially meaningful longitudinal analyses on grandmothers who actually transitioned from pre- to post-menopausal status.

To address these limitations, the analyses that comprise Study 2 were conducted on data obtained from a larger sample of pre- and post-menopausal women residing in a different country (Australia).

3. Study 2

Data were obtained from the Australian Longitudinal Study on Women's Health (ALSWH), information about which is available online at http://www.alswh.org.au (see also Dobson et al., 2015). Since 1996, the ALSWH has been collecting data every 2 or 3 years on participants in specific age groups. We conducted analyses on data obtained from women within a mid-life sample, a sample which included both pre and post-menopausal women. Prior to 1998, no measure of child care was assessed. Therefore, our analyses focused on data collected in 5 subsequent time periods (1998, 2001, 2004, 2007, 2010).

3.1. Methods

3.1.1. Participants

All ALSWH participants in the mid-life sample were female and between the ages of 30 and 80. Their data were included in analyses if these data identified them explicitly as either pre- or post-menopausal, and if they provided a response to the measure assessing grandparental caregiving (measures of both variables are described below). Based on these inclusion criteria, we conducted analyses on a total of 25,066 observations across the five time points (1998, 2001, 2004, 2007, and 2010). These data were provided by 8,290 discrete individuals (1,320 provided responses at one time point, 1,487 at two time points, 2,244 at three time points, 2,155 at four time points, and 1,084 at all five time points). Participants' ages ranged from 47-52 in 1998; in subsequent years, participants were correspondingly older. For additional information on participants, see Supplementary Materials, Table S11.

The ALSWH project did not include a measure assessing participants' status as a grandparent. Therefore, in contrast to Study 1, this sample of pre- and post-menopausal women was not restricted to grandmothers.

3.1.2. Variables of Primary Conceptual Interest

Menopause status. Each ALSWH observation was identified as belonging to one of several different categories pertaining to their reproductive status (e.g. pre-menopause, post-menopause, hysterectomy, oophorectomy, menopausal hormone therapy use, etc.). We included only those observations that were identified explicitly as either pre-menopause or post-menopause. Of the total of 25,066 observations across the five time points, 3,819 were classified as pre-menopause and 21,246 as post-menopause.

Grandparental Caregiving. The ALSWH project did not include items assessing caregiving specifically to grandchildren. However, participants did provide a response to the question, "Do you regularly provide unpaid care for grandchildren or other people's children?" Responses were provided on the following 4-point scale: 1 = No, never, 2 = Yes, occasionally; 3 = Yes, weekly, 4 = Yes, daily. We employed these responses as a measure of grandparental caregiving. (Although we refer to this variable as "grandparental caregiving" for the sake of consistency with Study 1, some unidentifiable subset of responses may instead represent unpaid care given to other children, some of whom might not actually be kin.)

Volunteering. Data collected at one time point (1998) did not include a measure of volunteering. Across the other 4 time points, a subset of 19,126 observations (pre-menopause = 1,111, post-menopause = 18,015) indicated whether their total number of weekly volunteer hours fell into one of seven categories: 1 = 0 hours; 2 = 1-15 hours; 3 = 16-24 hours; 4 = 25-34

hours; 5 = 35-40 hours; 6 = 41-48 hours; 7 = 49 hours or more. We employed these responses as a measure of volunteering.

3.1.3. Control Variables

As in Study 1, we identified a set of variables that might plausibly be related to both menopause status and grandparental caregiving. These included variables pertaining to women's age, health, and access to resources. In addition, as in Study 1, we also employed a systematic data-driven strategy to identify additional variables in the ALSWH dataset that were correlated with both menopause status and grandparental caregiving. Focusing specifically on data obtained in 1998 (the time point with the largest sample of pre-menopausal women), we computed the zero-order correlation between every variable in the dataset and both menopause status and grandparental caregiving. (There were a total of 190 variables in the dataset; and for all them there were responses from a minimum of 250 total women and a minimum of 50 pre-menopausal and 50 post-menopausal women.) If a variable correlated with both menopause status and grandparental caregiving at a magnitude of at least $r = \mid .15 \mid$ it was to be included as a control variable. In fact, no variable met this threshold. The full set of control variables is as follows:

Age. A subset of 25,065 observations (3,820 pre-menopausal, 21,245 post-menopausal) provided an age. (Combining across all time points, correlations with menopause status and grandparental caregiving were $r = .61$ and $r = .16$, respectively.)

Health. A subset of 24,939 observations (3,798 pre-menopausal, 21,141 post-menopausal) provided an overall health rating (on a 5-point scale, higher values indicating better health). We employed this variable as a measure of *perceived health*. (Combining across all time points, correlations with menopause status and grandparental caregiving were $r = -.09$

and $r = .05$, respectively.) Also, a subset of 24,859 observations (3,792 pre-menopausal, 21,067 post-menopausal) provided a rating on the physical functioning subscale of the 36-item Short-Form Health Survey (Ware & Sherbourne 1992). This subscale measures how much people are limited by their health when preforming ten day-to-day activities (e.g. lifting or carrying groceries, climbing one flight of stairs). An index of *physical functioning* (Cronbach's alpha=.89) was computed as outlined in the scoring manual, with higher values representing better health. (Combining across all time points, correlations with menopause status and grandparental caregiving were $r = -.11$ and $r = -.05$, respectively.)

Temporal Resources. A subset of 24,839 observations (3,782 pre-menopausal, 21,057 post-menopausal) provided ratings (on 5-point scales) of how often they felt too busy, and how often they had extra time on their hands that they did not know how to fill. After reverse-scoring responses to the latter item, the mean of these two ratings was computed to create an index of *perceived time pressure* (Cronbach's alpha=.26). (Combining across all time points, correlations with menopause status and grandparental caregiving were $r = -.07$ and $r = .02$, respectively.) Additionally, a subset of 23,286 observations (3,636 pre-menopausal, 19,650 post-menopausal) provided a rating of how many hours per week they spent doing some sort of work for pay. Although the exact nature of this item—and its response format—differed at different time points, we were able to create a single index assessing *hours of paid work.* (Further details on this calculation is available in Supplemental Materials; Combining across all time points, correlations with menopause status and grandparental caregiving were $r = -.13$ and $r = -.15$, respectively.)

Financial Resources. The ALSWH dataset did not include a measure of actual income, but a subset of 23,108 observations (3,605 pre-menopausal, 19,503 post-menopausal)

provided a rating (on a 5-point scale) of how well they managed on their available income. We employed this variable as a measure of *perceived financial comfort*, with higher values representing greater financial comfort. (Combining across all time points, correlations with menopause status and grandparental caregiving were $r = .02$ and $r = -.04$, respectively.)

3.2. Results

3.2.1. Relation between Menopause Status and Grandparental Caregiving

In order to test the primary hypothesis, we conducted analyses that were analogous to those reported for Study 1—including analyses on data obtained during specific time points, as well as HLM analyses on the full set of data across all 5 time points.

For two of the time points (2007 and 2010) there were fewer than 20 pre-menopausal women; therefore, we did not conduct time point specific analyses for these two years. Table 3 reports the mean level of grandparental caregiving reported by pre- and post-menopausal women during each of the other three time points (1998, 2001, 2004). For each of these time points, we conducted an ANCOVA predicting grandparental caregiving from menopause status, while controlling for age. Results revealed that, for all three time points, the mean level of grandparental caregiving was higher among post-menopausal women than pre-menopausal women; and for two of these time points—1998 and 2001—this mean difference was statistically significant, *p's* < .05 (see Table 3).

Table 3. *Cross Sectional Analysis of Grandparental caregiving reported by pre- and post-menopausal women in the Australian Longitudinal Study on Women's Health.*

	Pre-Menopausal Women		Post-Menopausal Women			
Time point	*n*	*M (SD)*	*N*	*M (SD)*	Cohen's *d*	*p*
1998	2581	1.43 (.64)	1269	1.53 (.71)	0.16	.001
2001	1005	1.50 (.78)	2749	1.61 (.82)	0.17	.044
2004	216	1.61 (.84)	5044	1.66 (.83)	0.06	.867

Note: p-values from ANCOVA predicting grandparental caregiving from menopause status, while controlling for grandmother's age.

Subsequent analyses were conducted on data combined across all five time points, using hierarchical linear modeling (HLM). Initially, we conducted a linear mixed effects analysis of the relationship between menopause status and grandparental care, controlling for age. Repeated measures of menopause status (Level 1) were nested within individuals (Level 2). Within each participant, repeated measures of age at each time point was group mean centered and used as a level 1 predictor; in addition, a participant's average age across all time points was grand mean centered and used as a level 2 predictor. Menopause status was dummy coded (0=pre-menopause; 1=post-menopause) and used as a level 1 predictor. A random intercepts model was computed, employing the following equations:

Level 1: Grandparental Caregiving$_{ti}$ $= \pi_{0i} + \pi_{1i}$ (Menopause Status$_{ij}$) $+ \pi_{2i}$(Age) $+ e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + \beta_{01}$ (Average Age) $+ r_{0i}$

Results revealed that, controlling for age, menopause status significantly predicted

grandparental caregiving (b=0.03, SE=0.02, p=.035).

Table 4. *Results of HLM analysis on the Australian Longitudinal Study of Women's Health dataset, predicting grandparental caregiving from menopause status and all control variables.*

	Grandparental Caregiving Coefficient	SE	p
Intercept	1.644	0.02	< .001
Menopause Status	0.036	0.02	.032
Age (Level 1)	0.026	0.00	< .001
Age (Level 2)	0.022	0.00	< .001
Perceived Health (Level 1)	-0.003	0.01	.784
Perceived Health (Level 2)	-0.019	0.01	.327
Physical Functioning (Level 1)	0.000	0.00	.067
Physical Functioning (Level 2)	-0.005	0.00	.950
Perceived Time Pressure (Level 1)	0.048	0.01	< .001
Perceived Time Pressure (Level 2)	0.042	0.01	< .001
Hours of Paid Work (Level 1)	-0.005	0.00	< .001
Hours of Paid Work (Level 2)	-0.006	0.00	< .001
Perceived Financial Comfort (Level 1)	-0.001	0.01	.908
Perceived Financial Comfort (Level 2)	-0.039	0.01	< .001

Note. Level 1 *n*= 22983, Level 2 *n*= 8126. Premenopause *n* = 3,593; Postmenopause *n* = 19,390. Menopause Status coded as 0 = pre-menopause, 1 = post-menopause; ICC = .47; Deviance reduction from final model to empty model= 1215, which represents a significant reduction in deviance. HLM analysis employed full maximum likelihood estimation. Unstandardized regression coefficients are presented.

We also conducted a final HLM analysis that included all control variables (in addition

to menopause status) as predictors of grandparental care:

Level 1: Grandparental Caregiving$_{ti}$ $=$ π_{0i} + π_{1i}(Menopause Status$_{ij}$) + π_{2i}(Age) + π_{3i}(Perceived Health) + π_{4i}(Physical Functioning) + π_{5i}(Perceived Time Pressure) + π_{6i}(Hours of Paid Work) + π_{7i}(Perceived Financial Comfort) + e_{ti}

Level 2: π_{0i} = β_{00} + β_{01}(Average Age) + β_{02}(Average Perceived Health) + β_{03}(Average Physical Functioning) + β_{04}(Average Perceived Time Pressure) + β_{05}(Average Hours of Paid Work) + β_{06}(Average Perceived Financial Comfort) + r_{0i}

Results are presented in Table 4. These results show that, even when controlling statistically for a wide range of variables that might plausibly be correlated with both menopause status and grandparental caregiving, menopause status remained a statistically significant predictor of grandparental caregiving.

3.2.2. Relation between Menopause Status and Volunteering

In order to test whether menopause status also predicted volunteering, we conducted HLM analyses analogous to those reported immediately above. One analyses included just menopause status and age as predicators of volunteering. There was no statistically significant effect of menopause status; if anything, the effect was in the opposite direction (b= -.03, SE=0.02, p=.11). A second analysis included menopause status and all control variables as predictors. Again, there was no significant effect of menopause status (b= -.01, SE=0.02, p=.35).

3.2.3. Longitudinal Analyses on Women Whose Menopause Status Changed

The ALSWH dataset included 2,048 women who provided grandparental caregiving data during at least one pre-menopause and at least one post-menopause time point. We conducted longitudinal analyses on this subset of women, to test whether the transition from pre to post menopause was associated with a change in their grandparental caregiving. For each woman, mean grandparental caregiving scores were computed separately for premenopausal and postmenopausal time points. These means are presented in Table 5, and reveal that these

women reported higher levels of grandparental caregiving after going through menopause than they did before going through menopause. A repeated-measures Analysis of Variance (ANOVA) shows these means to be significantly different, $F(1, 2047) = 240.14$, $p<.001$.

Table 5. *Mean grandparental caregiving and volunteering reported by women in the ALSWH dataset who provided responses both before and after going through menopause.*

	n	Pre-Menopause M (SD)	Post-Menopause M (SD)	Mean Difference	95% CI	Cohen's d	p
Grandparental Caregiving	2048	1.47 (.64)	1.74 (.77)	.27	[.24, .31]	0.38	<.001
Volunteering	744	1.32 (.61)	1.36 (.56)	.04	[.00, .09]	0.07	.042

Note: *p*-value is from repeated-measures ANOVA predicting outcome variable from menopause status.

Because this analysis is longitudinal, it controls for individual differences between women; but it is difficult to disentangle a woman's change in menopause status from aging. (Within this subset of data, there was a near-perfect correlation between women's age and their pre-menopause / post-menopause status, $r = .93$.) Nevertheless, we attempted to account for aging by conducting a repeated-measures ANCOVA that included as a covariate the mean number of years elapsed between pre- and post-menopause datapoints. (Following recommended procedures for repeated-measures ANCOVA, the covariate was mean-centered prior to its inclusion in the analysis; Schneider, Avivi-Reich, & Mozuraitis, 2015.) Results revealed the same significant main effect of menopausal status ($F(1, 2045) = 241.26$, $p <$

.001[2]), no main effect of the covariate ($F(1, 2045) = 0.84$, $p = .260$), and a significant

interaction between menopause status and the covariate ($F(1, 2045) = 10.37$, $p = .001$). The

latter effect indicates that the relation between menopause status and grandparental caregiving

was larger among women for whom more years elapsed between pre- and post-menopause

measures of grandparental caregiving.

A smaller subset of these women ($n=744$) also provided data on volunteering during at

least one pre-menopause and one post-menopause time point. For each of these women, mean

volunteering scores were computed separately for premenopausal and postmenopausal time

points. A repeated-measures ANOVA on these means indicated a significantly higher level

post-menopause volunteerism, $F(1, 743) = 4.17$, $p=.042$; this effect was much weaker in

magnitude than the effect on grandparental caregiving (see Table 5). (This effect remained

significant when controlling for aging with a repeated-measures ANCOVA analogous to that

described in the preceding paragraph $F(1, 742) = 4.20$, $p=.041$.)

3.3. Discussion

Results from Study 2 indicated that, compared to pre-menopausal women, post-

menopausal women engage in more grandparental-like caregiving behavior. This effect held

even when statistically controlling for a wide range of potentially confounding variables. These

results from Study 2—conducted on a larger sample and wider range of women (which

included but was not exclusive to grandmothers)—corroborate findings from Study 1. Included

within the Study 2 dataset were 2,048 women who provided data on grandparental caregiving

during at least one pre-menopause and one post-menopause time point. Longitudinal analyses

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[2] Mean number of years elapsed could not be computed for one woman due to a data
inaccuracy (reported age was higher at premenopause than postmenopause). This woman's
data was removed from the ANCOVA.

on these data further corroborated analyses on the full dataset, showing that the menopausal transition was associated with increased investment in grandparental caregiving.

Results on menopause status and volunteering were more equivocal. Longitudinal analysis on a small subset of women indicated some increase in volunteering following menopause, but the size of this effect was much smaller than the post-menopausal increase in grandparental caregiving. And, on the full dataset, there was no analogous relationship between menopause status and volunteering. These results suggest that any effect of menopause on altruistic behavior may occur primarily in behavioral domains that represent (or mimic) kin-directed caregiving.

4. General Discussion

Results from both studies showed that, compared to pre-menopausal women, post-menopausal women devoted more time to grandparental caregiving. This effect held even when statistically controlling for women's age, health, access to resources, and other potential confounding variables. These results are consistent with a previously-untested behavioral implication of the grandmother hypothesis. Additional results from both studies showed that, in contrast to its relation to grandparental caregiving, menopause status was not as strongly related to a different measure of altruistic behavior (volunteering). The domain-specificity of the menopause effect is also consistent with the underlying logic of the grandmother hypothesis.

The observed relation between menopause and grandparental caregiving is also consistent with theory and research regarding the trade-off between mating effort and parenting effort (Beall and Schaller, in press; Del Giudice, Gangestad, & Kaplan, 2016). If menopause is characterized by inhibition of mechanisms that regulate mating behavior (as indicated, for

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instance, by the association between menopause and reduced sexual desire; Avis, Stellato, Crawford, Johannes, & Longcope, 2000; Dennerstein, Koochaki, Barton, & Graziottin, 2006), there may a compensatory increase in activation of mechanisms that regulate parental caregiving behavior. Empirical evidence indicates that these parental caregiving motivational mechanisms facilitate protective and nurturant responses not only to individuals' own offspring, but also to vulnerable young children more generally (Buckels et al., 2015; Hofer et al., in press). Consequently, post-menopausal women may be more highly motivated to provide care to grandchildren and other juvenile kin, and perhaps even to unrelated children. Any such effect is likely to be the product of specific neurochemical changes associated with menopause; the elucidation of these underlying mechanisms remains a task for future research.

In the two studies reported here, grandparental caregiving was operationalized in one specific way: Time spent providing childcare. But grandmothers do more than just devote temporal resources to their grandchildren; they may also provide tangible resources, such as money and food. Indeed, it has been speculated that indirect fitness benefits associated with grandmother-to-grandchild food-sharing may have played a primary role in the evolution of menopause and post-menopausal longevity (Hawkes, 2016). Modern-day grandmothers are famous for spoiling their grandchildren with high calorie treats, often in excess of parental wishes. As a form of conceptual replication, it would be useful for future research to test whether grandmothers' provision of food (and other tangible resources) to grandchildren also increases after menopause.

Additionally, it would be useful for future research to test whether any post-menopausal increase in grandparental care-giving might vary according to the logic linking parental uncertainty to grandparental investment (Bishop, Meyer, Schmidt, & Gray, 2009; Chrastil,

Getz, Euler & Starks, 2006; Michalski and Shackelford, 2005; Pollet, Nelissen, & Nettle, 2009). From a grandmother's perspective, grandchildren produced by a daughter are more highly certain to be kin, whereas there is some higher degree of uncertainty regarding the genetic relatedness of grandchildren produced by a son. Consequently, one might expect a greater post-menopausal increase in grandparental caregiving to daughters' offspring compared to sons' offspring.

These two studies focused primarily on the provision of care to grandchildren. It would also be useful for future research to rigorously assess pre- and post-menopausal caregiving to a wider range of kin. By doing so, one could directly test whether the post-menopausal increase in grandparental caregiving generalizes to other kin and, if so, whether the magnitude of the effect varies depending on degree of relatedness. One could also test the plausible hypothesis that any post-menopausal increase in caregiving to non-grandchild kin (and perhaps even to non-kin) might be most pronounced among women without any grandchildren.

The hypothesized relationship between menopause status and kin care is based on the logic of inclusive fitness—specifically the indirect fitness implications associated with activities that affect the reproductive outcomes of children, grandchildren, and other kin. Overtly altruistic behaviors (exemplified by grandparental caregiving) are not the only activities that can have such indirect fitness implications. Indirect fitness benefits may also accrue from behaviors that encourage one's kin to take mates who will help them to produce and raise reproductively viable offspring. Empirical evidence shows that people do meddle in the mating affairs of their kin in ways that promote their inclusive fitness (Buunk, Park, Dubbs, 2008; Faulker and Schaller, 2007). It is possible that post-menopausal women might be especially likely to do so. Future empirical research testing the effect of menopause on this

kind of "nepotistic nosiness"—and on other non-obvious forms of indirect-fitness-relevant behavior—may facilitate a more complete understanding of the contemporary behavioral implications associated with the grandmother hypothesis.

References

Alberts, S. C., Altmann, J., Brockman, D. K., Cords, M., Dedigan, L. M., et al. (2013).

    Reproductive aging patterns in primates reveal that humans are distinct. *Proceedings of*

    the National Academy of Sciences, 110, 13440-13445.

Avis, N. E., Stellato, R., Crawford, S., Johannes, C., & Longcope, C. (2000). Is there an

    association between menopause status and sexual functioning?. *Menopause, 7*, 297-309.

Bates, D.M., Mächler, M., & Bolker, B.,Walker, B., (2015). lme4: Fitting Linear Mixed-

    Effects Models Using lme4. *Journal of Statistical Software, 67*, 1-48.

    https://doi.org.10.18637/jss.v067.i01

Beall, A. T., & Schaller, M. (in press). Evolution, motivation, and the mating/parenting trade–

    off. *Self and Identity*, https://doi.org.10.1080/15298868.2017.1356366

Bishop, D. I., Meyer, B. C., Schmidt, T. M., & Gray, B. R. (2009). Differential investment

    behavior between grandparents and grandchildren: The role of paternity uncertainty.

    Evolutionary Psychology, *7*, https://doi.org.10.1177/147470490900700109

Buckels, E. E., Beall, A. T., Hofer, M. K., Lin, E. Y., Zhou, Z., & Schaller, M. (2015).

    Individual differences in activation of the parental care motivational system:

    Assessment, prediction, and implications. *Journal of Personality and Social*

    Psychology, 108, 497-514. http://dx.doi.org/10.1037/pspp0000023

Buunk, A. P., Park, J. H., & Dubbs, S. L. (2008). Parent-offspring conflict in mate preferences.

    Review of General Psychology, 12, 47.

Chrastil, E. R., Getz, W. M., Euler, H. A., & Starks, P. T. (2006). Paternity uncertainty

    overrides sex chromosome selection for preferential grandparenting. *Evolution and*

    Human Behavior, *27*, 206-223. https://doi.org/10.1016/j.evolhumbehav.2005.09.002

Del Giudice, M., Gangestad, S. W., & Kaplan, H. S. (2016). Life History Theory and

Evolutionary Psychology. In D. M. Buss (Ed.), *The Handbook of Evolutionary*

Psychology (pp. 88-114). Hoboken, NJ: Wiley.

Dennerstein, L., Koochaki, P., Barton, I., & Graziottin, A. (2006). Hypoactive sexual desire

disorder in menopausal women: a survey of Western European women. *The Journal of*

Sexual Medicine, 3, 212-222. https://doi.org.10.1111/j.1743-6109.2006.00215.x

Dobson, A. J., Hockey, R., Brown, W. J., Byles, J. E., Loxton, D. J., McLaughlin, D., Tooth,

L.R., & Mishra, G. D. (2015). Cohort profile update: Australian longitudinal study on

women's health. *International Journal of Epidemiology*, *44*, 1547-1547f.

https://doi.org.10.1093/ije/dyv110

Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel

models: a new look at an old issue. *Psychological Methods*, *12*, 121.

https://doi.org.10.1037/1082-989X.12.2.121

Faulkner, J., & Schaller, M. (2007). Nepotistic nosiness: Inclusive fitness and vigilance of kin

members' romantic relationships. *Evolution and Human Behavior*, *28*, 430-438.

https://doi.org/10.1016/j.evolhumbehav.2007.06.001

Fox M., Sear R., Beise J., Ragsdale G., Voland E., Knapp L. A. (2009). Grandma plays

favourites: X-chromosome relatedness and sex-specific childhood mortality.

Proceedings of the Royal Society of London B: Biological Sciences, *277*, 567–573.

https://doi.ord/10.1098/rspb.2009.1660

Hawkes, K., & Coxworth, J. E. (2013). Grandmothers and the evolution of human longevity: a

review of findings and future directions. *Evolutionary Anthropology: Issues, News, and*

Reviews, *22*, 294-302. https://doi.org.10.1002/evan.21382

Hawkes, K. (2016). Ethnoarchaeology and Plio-Pleistocene sites: Some lessons from the

    Hadza. *Journal of Anthropological Archaeology, 44*, 158-165.

Hawkes, K., O'Connell, J. F., & Blurton Jones, N. G. (1989). Hardworking Hadza

    Grandmothers. In V. Standen and R. A. Foley (Eds.), *Comparative Socioecology: The*

    Behavioural Ecology of Humans and Other Mammals (pp. 341-366). Oxford:

    Blackwell Scientific Publications.

Health and Retirement Study (2017), RAND public use dataset. Produced and distributed by

    the University of Michigan with funding from the National Institute on Aging (grant

    number NIA U01AG009740). Ann Arbor, MI.

Hill, K., & Hurtado, A. M. (1991). The evolution of premature reproductive senescence and

    menopause in human females. *Human Nature*, *2*, 313-350.

    https://doi.org.10.1007/BF02692196

Hofer, M. K., Buckels, E. E., White, C. J. M., Beall, A. T., & Schaller, M. (in press). Individual

    differences in activation of the parental care motivational system: An empirical

    distinction between protection and nurturance. *Social Psychological and Personality*

    Science.

Lahdenperä, M., Lummaa, V., Helle, S., Tremblay, M., & Russell, A. F. (2004). Fitness

    benefits of prolonged post-reproductive lifespan in women. *Nature*, *428*, 178–181.

    https://doi.org/10.1038/nature02367

Michalski, R. L., & Shackelford, T. K. (2005). Grandparental investment as a function of

    relational uncertainty and emotional closeness with parents. *Human Nature*, *16*, 293-

    305. http://dx.doi.org.ezproxy.library.ubc.ca/10.1007/s12110-005-1012-5

Pollet, T. V., Nelissen, M., & Nettle, D. (2009). Lineage based differences in grandparental

investment: evidence from a large British cohort study. *Journal of Biosocial Science*, *41*, 355-379. https://doi.org.10.1017/S0021932009003307

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Rilling, J. K. (2013). The neural and hormonal bases of human parental care. *Neuropsychologia, 51*, 731–747.

Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize?. *Journal of Research in Personality*, *47*, 609-612. https://doi.org.10.1016/j.jrp.2013.05.009

Sear, R., & Mace, R. (2008). Who keeps children alive? A review of the effects of kin on child survival. *Evolution and Human Behavior*, *29*, 1-18. https://doi.org/10.10116/j.evolhumbehav.2007.10.001

Sear, R., Mace, R., & McGregor, I. A. (2000). Maternal grandmothers improve nutritional status and survival of children in rural Gambia. *Proceedings of the Royal Society of London B: Biological Sciences / The Royal Society*, *267*, 1641–1647. https://doi.org/10.1098/rspb.2000.1190

Schwarz, F., Spring, S. A., Altheide, T. K., Varki, N. M., Gagneux, P., & Varki, A. (2016). Human-specific derived alleles of *CD33* and other genes protect against postreproductive cognitive decline. *Proceedings of the National Academy of Sciences, 113*, 74-79.

Schneider, B. A., Avivi-Reich, M., & Mozuraitis, M. (2015). A cautionary note on the use of the Analysis of Covariance (ANCOVA) in classification designs with and without

within-subject factors. *Frontiers in Psychology*, *6*, 474.

http://doi.org/10.3389/fpsyg.2015.00474

Ware, J. E., & Sherbourne C. D. (1992). The MOS 36-Item Short-Form Health Survey.

Medical Care, 30, 473-483.

Williams G. C. (1957). Pleiotropy, natural selection, and the evolution of senescence.

Evolution 11: 398–411. https://doi.org.10.2307/2406060