



Three-Generation Education Patterns among Grandparents, Parents and Grandchildren: Evidence of Grandparent Effects from Australia

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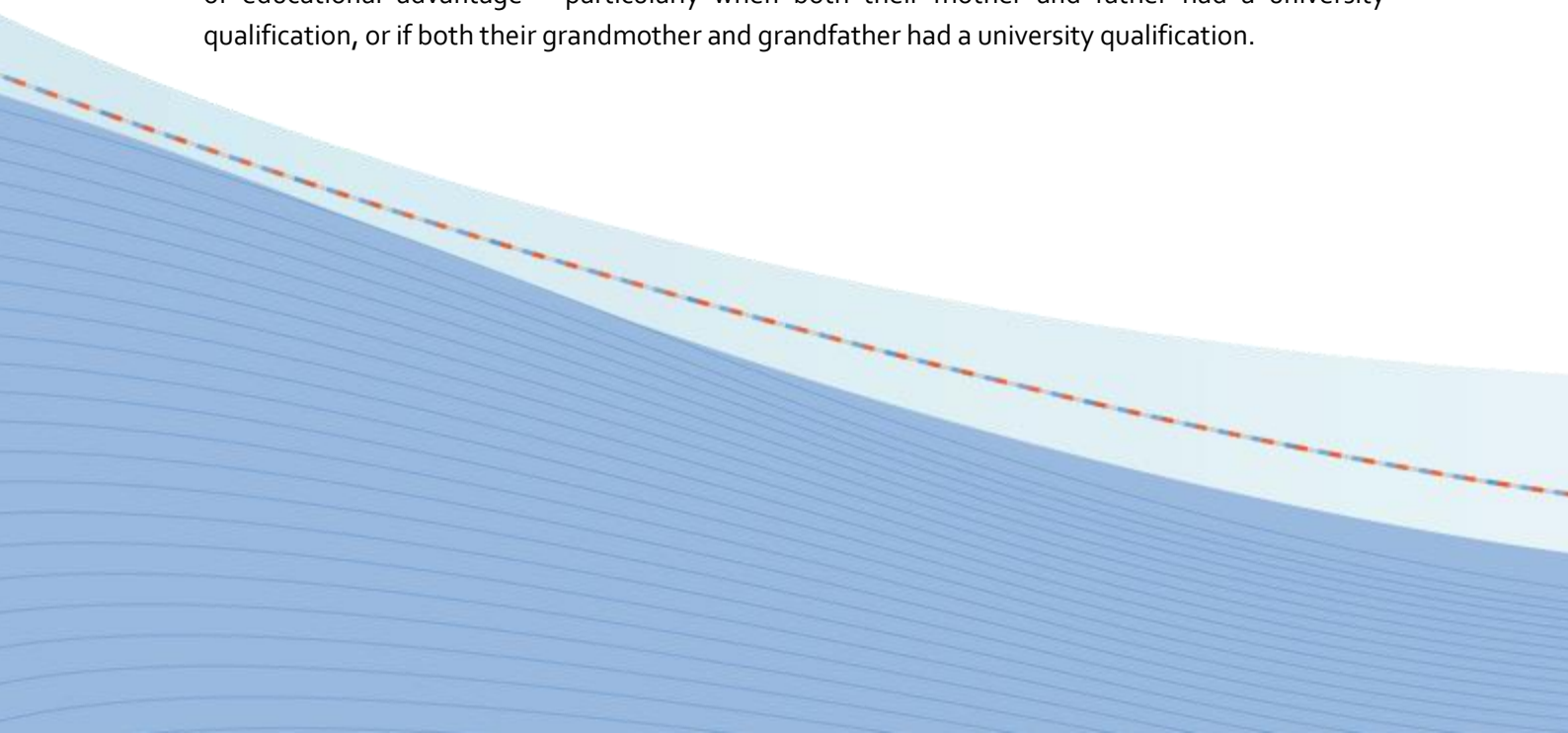
NON-TECHNICAL SUMMARY

Both in Australia and internationally it is well-established that social and economic advantage tends to persist from one generation to the next. For example, the educational attainment of parents strongly corresponds with the educational attainment of their children once they reach adulthood. In recent years, the international literature has turned to examining how education outcomes are transferred across three generations, from grandparents to parents to grandchildren. This working paper provides a description of what these patterns look like in Australian families.

Using data from the Longitudinal Study of Australia, we map out how the educational attainment of grandparents corresponds with the educational attainment of parents, and in turn, how the educational attainment of both grandparents and parents predict reading and numeracy scores among grandchildren. We examine these relationships for mothers, fathers, maternal grandmothers, maternal grandfathers, paternal grandmothers and paternal grandfathers.

As expected, higher levels of education among grandparents were associated not only with higher levels of parent education, but also with numeracy and reading achievement scores among their grandchildren, and the association between grandparents and grandchildren remained even after accounting for parent education. We also found that the likelihood of mothers or fathers completing a university degree was higher if their own parents had a university qualification, but also if their partner or spouse's parents had a university qualification, suggesting that the human capital that grandparents pass on to their offspring increases not only their offspring's likelihood of attaining high levels of education, but also their likelihood of partnering with a highly educated person.

The effect of higher educational attainment in grandparents on parent and grandchild educational outcomes was broadly limited to grandparents who had obtained a university qualification. In a generation where few grandparents had an opportunity or expectation to attend university than the current generation of parents, we also find that mothers and fathers had higher educational attainment if grandparents—and grandfathers in particular—showed a lot of interest in education while parents were growing up, irrespective of grandparent education level. Finally, we also found that achievement scores of grandchildren were substantially higher in families with concentrations of educational advantage – particularly when both their mother and father had a university qualification, or if both their grandmother and grandfather had a university qualification.



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Abstract

The ways in which parents invest their human capital resources in the development of their children is well established, however the transfers of resources across multiple generations is less understood, particularly in Australia. Drawing upon information from the Longitudinal Study of Australian Children about the educational attainment of maternal and paternal grandmothers and grandfathers, mothers and fathers, we find that the likelihood of mothers and fathers completing Year 12 or a university qualification is higher among those whose own parents had higher educational attainment. Among families where grandparents had lower educational attainment, both mothers and fathers had a greater likelihood of completing Year 12 or a university qualification if grandparents—particularly grandfathers—showed interest in their education while parents were growing up. Controlling for parent educational attainment, grandchildren had higher numeracy scores if their paternal grandfather was university qualified and higher reading scores if maternal or paternal grandmothers were university qualified. We also find that achievement scores were substantially higher among children in families with concentrations of educational advantage. These results suggest that the concentration of human capital in families contributes to educational inequalities across multiple generations.

Keywords: human capital; grandparents; intergenerational mobility; multiple generations; educational attainment; inequality

1. Introduction

Traditionally, studies of the acquisition, development and expansion of human capability across the life course have focused on the forms of human, social and psychological capital that parents possess and invest in their children (Zubrick, Taylor, Lawrence, Mitrou, Christensen, & Dalby, 2009). Broadly, the more resources that parents have, the better able they are to provide the emotional, educational, financial and social resources to their children that promote health (Kahn, Wilson, & Wise, 2005), social-emotional wellbeing (Mistry, Vandewater, Huston, & McLoyd, 2002; Yeung, Linver, & Brooks-Gunn, 2002) and cognitive development (Bradley & Corwyn, 2002; Duncan & Brooks-Gunn, 1997). Each of these developmental domains assists in the expansion of human development and capability across the life course, that is, the ability of individuals to participate economically, socially and civically throughout life (Sen, 1999). The international literature is broad and well-established, and consistently shows that social and economic advantage tends to persist from one generation to the next. As children from advantaged households grow up and have families of their own, the educational and social opportunities afforded to them by their parents throughout childhood and adolescence can then influence their ability as adults to invest in the development of their own children and their onward capability trajectories.

In this context, theories of capital transfers across more than two generations have adopted a 'Markovian' approach, whereby any association between higher levels of resources in grandparents and better outcomes for their grandchildren occurs only via the parent generation, and with the transfer of resources directly from one generation to the next (Becker & Tomes, 1986). In recent years the increased availability of survey and administration data across multiple generations of family members has allowed researchers to challenge this assumption, and to identify other potential ways in which grandparent capital may influence the outcomes of their grandchildren (Hagestad, 2006; Mare, 2011, 2015; Pfeffer, 2014; Solon, 2014). The result has been a rapidly expanding literature addressing the role of grandparents in families and how the capital resources of grandparents may contribute—directly or indirectly—to the outcomes of their grandchildren. The focus has been predominantly on grandparent educational attainment and the onward educational outcomes of adult grandchildren (e.g. Bol & Kalmijn, 2016), though other studies have also examined the role of occupational status or social class (Chan & Boliver, 2013; Hertel & Groh-Samberg, 2014; Lindahl, Palme, Sandgren Massih, & Sjogren, 2014; Warren & Hauser,

1997), neighborhood effects (Sharkey & Elwert, 2011), joblessness (Hancock, Edwards, & Zubrick, 2013), and mental health (Hancock, Mitrou, Shipley, Lawrence, & Zubrick, 2013). For this study, we focus on reviewing and contributing to the literature concerning educational attainment as a key marker of human capital resources that may be transferred across generations.

To date, the evidence regarding bivariate associations between grandparent educational attainment and the educational outcomes of their grandchildren has been clear. As we would hypothesize through Markovian processes, highly educated grandparents tend to have highly educated children and grandchildren. This pattern has been consistently found across multiple countries including the United States (Daw & Gaddis, 2016; Hertel & Groh-Samberg, 2014; Jæger, 2012; Lawrence, 2016; Loury, 2006; Warren & Hauser, 1997; Wightman & Danziger, 2014), the Netherlands (Bol & Kalmijn, 2016), Chile (Celhay & Gallegos, 2015), Taiwan (Chiang & Park, 2015), Sweden (Hällsten, 2014; Lindahl, et al., 2014; Modin, Erikson, & Vagero, 2013), Denmark (Møllegaard & Jæger, 2015), the United Kingdom (Sauder, 2006) and rural China (Zeng & Xie, 2014), and across multiple measures of attainment, including school completion, selection into academic school tracks, and completing a university degree. Most studies examine the educational attainment of grandchildren in early adulthood, with some examining earlier indicators of educational success, such as achievement scores at school (Ferguson & Ready, 2011; Hill & O'Neill, 1994; Modin, et al., 2013).

However, while the bivariate grandparent/grandchild associations have been consistent, research that examines the nature and mechanisms associated with these relationships has produced equivocal results. Many of the three-generation studies have considered 'direct' grandparent effects as a starting point, which are considered to be present if a significant association between grandparent education and grandchild educational outcomes remains after controlling for parent education. The rationale for direct grandparent effects is straightforward. As broader models of human capability development across the life course reflect (Zubrick, et al., 2009), parents are not the only influence in a child's life, nor are they the only ones who invest resources in their children. Grandparents may also invest their human, psychological and social capital resources directly in grandchildren. Grandparents may provide a support role, for example by providing child care, which may enable parents to support their children through improved employment opportunities and financial security. They may also directly invest in grandchildren by assisting with education

costs, or by using their social networks to influence other opportunities for their grandchildren. These investments can be made across the lifespan of the grandchild, building the human capability profile of the grandchild from infancy to adulthood. As a result, grandparent resources may contribute to grandchildren's educational outcomes over and above the resources provided by parents.

Studies that control for parent education to determine if there are 'direct' grandparent effects independently of parent education effects have produced mixed results so far. Whereas some studies find an association between grandparent and grandchild education net of parent education (Celhay & Gallegos, 2015; Daw & Gaddis, 2016; Ferguson & Ready, 2011; Hällsten, 2014; Hill & O'Neill, 1994; Lindahl, et al., 2014; Modin, et al., 2013; Møllegaard & Jæger, 2015), others find no main effect (Bol & Kalmijn, 2016; Chiang & Park, 2015; Jæger, 2012; Warren & Hauser, 1997; Wightman & Danziger, 2014; Zeng & Xie, 2014). As Bol and Kalmijn (2016) observe, the variability in types of models, measures, data, and national or historical contexts likely contribute to these inconsistencies. Furthermore, when controls for the middle generation become more stringent in the models, the remaining effect of grandparent educational status become weaker (Bol & Kalmijn, 2016). This pattern might be expected, given that higher educational attainment among grandparents will provide more than just improved educational attainment in parents, including improvements in occupational class, income, and housing stability that higher education can provide, which in turn are beneficial for the educational trajectories of their grandchildren. Therefore, studies that find 'direct' effects of grandparents net of parent education status are unlikely to be finding direct effects. Instead, there is simply part of the grandparent/grandchild association that is unexplained by the data that has been included in the model.

One example of a mechanism that higher grandparent education potentially enables is the ability of offspring to partner with someone who also comes from a highly educated background. Daw and Gaddis (2016) found that grandparent education was associated with grandchild education net of parent education, but that the association was greatly reduced once spousal education was accounted for. They argued that spousal mediation, reflecting assortative partnering where individuals tend to partner with people from a similar educational background (Mare, 1991), is a key mechanism of the intergenerational transmission of educational advantage. Without assessing these alternative explanations, multigenerational studies are not considering the full range of mechanisms through which grandparent educational attainment may relate to the educational outcomes of grandchildren.

Some researchers (e.g. Møllegaard & Jæger, 2014; Bol & Kalmijn, 2016) suggest that just as different types of parent capital contribute to child development in different ways, so too do the different types of capital that grandparents possess. Møllegaard and Jæger (2014) propose three different types of capital that may act as inputs for grandchildren's educational trajectories. There may be direct financial transfers or support, for example, paying private school fees or assisting with other educational expenses (*economic capital*), a family culture that promotes academic education (*cultural capital*), or an ability to connect grandchildren with other highly educated families and the potential educational opportunities they may offer (*social capital*). Møllegaard and Jæger found that grandparents' cultural capital (but not economic or social capital) had a positive effect on the likelihood of grandchildren selecting the academic track in Denmark, and suggest that the ways grandparents affect grandchildren's educational success is via transmission or non-economic resources. However Bol and Kalmijn (2016) also examined the separate effects of grandparent educational attainment, occupational status and cultural resources for grandchild educational attainment, but found no evidence for any direct effect of these resources after accounting for each of these in parents. So again, the findings about the inter-generational contributions of different types of capital to the capabilities of the grandchildren are mixed.

The other important finding noted in the studies to date is that human capital transfers across generations are highly gendered processes. Very few studies have had information on the full grandparent pedigree (Bol & Kalmijn, 2016); most have examined only the maternal grandparents or paternal grandparents, or grandmothers versus grandfathers, but not both. While some studies have found grandparent effects on the grandchildren for both grandmothers and grandfathers (Modin, et al., 2013; Wightman & Danziger, 2014) for most studies these effects have been limited to grandfathers, or the effects have been stronger for grandfathers than grandmothers (Chan & Boliver, 2013; Chiang & Park, 2015; Hertel & Groh-Samberg, 2014; Modin, et al., 2013; Sauder, 2006). Loury (2006) found that the education of uncles and grandfathers had stronger effects on sons, whereas aunts and grandmothers had a stronger effect on daughters. For families in Chile, both grandmothers and grandfathers education was important for grandsons, while only grandmothers influenced granddaughters education (Celhay & Gallegos, 2015). They also found that the educational attainment of paternal grandmothers was more influential than of maternal grandmothers. Given such gendered effects, and that gendered effects likely vary across countries with different levels of educational equality between genders, it is important to examine the role of

educational attainment across both maternal and paternal lines, and both for grandmothers and grandfathers. The study we present here provides a rare opportunity to examine the educational attainment of the full pedigree of children's grandparents and its onward influence on their grandchildren in a large, nationally representative longitudinal study of Australian children followed from an early age.

2. Australian context and aims of current study

As in most other countries, data on the education characteristics of three generations of Australian families has only recently become available. There are several national or historical points of interest about the role of grandparents that may differ in the Australian context as compared to other countries. For example, Pilkauskas and Martinson (2014) demonstrated that grandparent-grandchild co-residence during early childhood is less prevalent in Australia (~11%) than in the United States (up to 25%), and is slightly higher than the United Kingdom (8%). Australia also has substantially higher rates of enrolment in private education, at almost 40% compared with an OECD average of 15%. Similar OECD countries like the United States, United Kingdom, Canada and New Zealand all have private education enrolments under 10% (OECD, 2011). Notwithstanding the expanding research indicating that there are few academic advantages to attending a private school once student-level socioeconomic characteristics have been taken into account (Li & Dockery, 2014; Mills, Heyworth, Rosenwax, Carr, & Rosenberg, 2009; Nghiem, Nguyen, Khanam, & Connelly, 2015; Thomson, De Bortoli, & Buckley, 2013), Australian grandparents may have more opportunities to invest financially in the education of their grandchildren, either by paying directly for school fees, or otherwise financially supporting parents to invest in their children this way.

Australia has also undergone significant education culture and policy shifts in recent decades. Most noteworthy has been the expansion in the proportion and gender ratio of Australians who obtain university qualifications. Higher education participation rates for school leavers more than doubled between 1982 and 2012 (Norton & Cherastidtham, 2014). In the 1950s, university places were predominantly male, at around 80%. Since that point, the share of university places taken up by women has steadily increased to just under 60%, and women have been the majority of university students since 1987. Norton and Cherastidtham (2014) note that this increase is due to several reasons, including improved social position,

higher education qualifications for traditionally female-dominated professions like teaching and nursing, and that men have better-paying vocational education options than young women. Research has also shown that with expanded accessibility to university positions and fee restructures (e.g. the Higher Education Contribution Scheme), participation in higher education in Australia has increased across all socioeconomic groups (Marks & McMillan, 2007).

Concurrently, the number of years of schooling that Australians are expected to complete has also expanded in recent decades. In 1980, high rates of student retention to the end of the compulsory Year 10 (91%) were achieved, at which point only a few students (35%) progressed onwards to complete Year 12. By 1990, following the introduction of targeted policies by the federal government, Year 12 retention rates had increased to 65% (Australian Bureau of Statistics, 1993) and by 2011 they had risen to 84% for females and 75% for males (Australian Bureau of Statistics, 2011). During the same period, the age at which children enter school also underwent change. While there is variability across states in expectations about starting ages and which aspects are compulsory, most Australian children are eligible for preschool in the year they turn four years of age. The variability in expectations and regulations means that some children in Australia will start Year 1 (age 6-years) with considerably more preparation than others. With these changes, compulsory education has been extended from around 10 or 11 years in 1980 to around 13 or 14 years for the majority of young people. This expansion in the number of compulsory years of schooling reflects broader societal expectations and assumptions about the value of education. The expansion may also reflect a desire from government to remain economically competitive with other developed nations. Modern economies have been restructuring towards knowledge-based employment, and the workforce must also transition to developing the appropriate skills. Increasing the amount of compulsory education assists in achieving that goal (OECD, 2007).

3. Aims and approach

In this study we draw upon data from the Longitudinal Study of Australian Children (LSAC), a study of two cohorts of children that has collected a range of information on children's academic achievement, the educational attainment of their parents, and the educational attainment of the full pedigree of the child's maternal and paternal grandmothers

and grandfathers, along with the interest that grandparents had in the parent's education while they were growing up. Our aim is to examine patterns of transfers of educational capital among Australian families. Given the variability in findings across the extant literature, and variability in educational contexts internationally, this first study does not attempt to distinguish between findings of other studies (i.e. of direct or indirect effects) but rather documents the extent to which educational advantage is transferred in Australian families, and how the educational resources of one generation combine to influence the educational outcomes of the next generation. A previous study has drawn upon the LSAC data to document the persistence of parental expectations and attitudes across generations. It found that grandparent educational attainment was associated with expectations of educational attainment in both parents and study children, but that grandparent educational attainment was not associated with expectations among grandchildren after controlling for parental expectations (Yu & Daraganova, 2015). In the current study, we therefore focus mainly on educational attainment data, and less on the data relating to attitudes, involvement and expectations.

This study provides a description of the associations between grandparent education and interest in education, parent education, and child academic achievement, and how much of the grandparent/child relationship can be accounted for by parents, and how these relationships vary for maternal and paternal grandmothers and grandfathers. We start by examining two-generation transfers, from grandparents to parents, by assessing how educational attainment and involvement in grandparents is differentially associated with not only with the educational attainment of their offspring, but also of their offspring's partner or spouse. We then expand to a three-generation model to examine the extent to which grandparent educational attainment is associated with children's reading and numeracy achievement scores at age 8–9 years, with and without controls for parent education. Finally, we use the context of assortative mating to assess the extent to which the concentration of educational advantage within families contributes to educational inequality in grandchildren.

3. Method

3.1 Study design and population

The LSAC is a nationally representative study of Australian children and their families. LSAC data were initially collected in 2004 from two cohorts of children, including

5,107 infants aged 3-19 months (B-cohort) and 4,983 children aged 4-5 years (K-cohort). The same study children were followed up every 2 years, with Wave 6 data collected in 2014. We draw upon data for both cohorts for this study. Table 1 provides an overview of the broad data collection schedule, along with the sample size and retention at each wave.

Table 1. Age range, sample size and study retention, B- and K-cohorts, Waves 1–6.

	Wave 1 (2004)	Wave 2 (2006)	Wave 3 (2008)	Wave 4 (2010)	Wave 5 (2012)	Wave 6 (2014)
B-Cohort						
Age (years)	0–1	2–3	4–5	6–7	8–9	10–11
Sample size	5,107	4,606	4,386	4,242	4,085	3,764
Sample retention (%)	-	90.2	85.9	83.1	80.0	74.0
K-Cohort						
Age (years)	4–5	6–7	8–9	10–11	12–13	14–15
Sample size	4,983	4,464	4,331	4,169	3,956	3,537
Sample retention (%)	-	89.6	86.9	83.7	79.4	71.0

The sampling methodology and design of LSAC has been extensively detailed elsewhere (Soloff, Lawrence, & Johnstone, 2005; Soloff, Lawrence, Misson, Johnstone, & Slater, 2006). Briefly, the LSAC sampling frame was based on the Medicare Australia enrolment database, which had an estimated coverage of 90% of children by 4 months of age, and 98% by 12 months (Soloff, et al., 2005). A two-stage clustered sample design was used, with Australian postcode area as the first-stage sampling unit (approximately 1-in-10 postcodes randomly selected), and children were then randomly selected within postcode area as the second-stage sampling unit. The initial response rate was 54.8% for the B-cohort and 47.0% for the K-cohort. Compared to the 2001 Australian Census, these initial samples were broadly representative of the Australian population of families with children in the relevant age group, but single-parent, non-English speaking families living in rental properties or in remote areas were under-represented (Soloff, et al., 2006). Over subsequent waves of data collection these same characteristics were over-represented in the families who dropped out of the study (Australian Institute of Family Studies, 2015; Siphthorp & Misson, 2009).

3.2 Data collection methods

The LSAC collects data from multiple informants. The majority of data were collected during in-home interviews conducted at each wave with the study child’s primary

carer (Parent 1). In addition to the interview, other collection methods included self-complete questionnaires for both Parent 1 and a second parent (Parent 2, where available), parents living elsewhere (PLE, typically a biological parent residing elsewhere following separation), teachers, carers and when old enough, from the study child. Direct assessments of the study child are also carried out by the interviewer, for example height and weight measurements, non-verbal intelligence assessments and executive functioning tests. Primary caregivers were also asked for consent to link survey data of the study child with external databases, including government administrative databases and national assessments of children's literacy and numeracy. Full details of the data collection methods and response rates for each method at each wave are available in the data user guide (Australian Institute of Family Studies, 2015).

3.3 Measures

3.3.1 Grandparent educational attainment and interest in education

To aid with clarity both in the description of measures and results, family members are referred to by their relationship to the study child, who in turn is referred to as the grandchild. For example, when describing how a mother's educational attainment varies by the educational attainment of her father, we refer to the father as the maternal grandfather, even when the association does not include a specific reference to the study child. In total, seven family members are referred to throughout the methods and results; grandchildren, mothers, fathers, maternal grandmothers, maternal grandfathers, paternal grandmothers and paternal grandfathers.

Information on maternal grandparent education was mainly collected from mothers during Wave 5 during the in-home interview, and information on paternal grandparent education was mainly collected from fathers using the Parent 2 self-complete questionnaire that was mailed back separately. The response rate on the mail-back survey was 70% among households where there was a Parent 2 (84% of households). Therefore 62% of participating households at Wave 5 provided Parent 2 data, which predominantly related to fathers and paternal grandparents. Mothers and fathers of the study child were each asked "When you were 14 years old, what was your mother's/father's highest educational qualification?" Ten response options were available, ranging from never attended school to a university qualification. To simplify these categories and collapse small cell sizes, these responses were combined to the following categories: University qualification; Post-school qualification

including a diploma/certificate, trade or apprenticeship; Year 11 or 12; Year 10; and Year 9 or less, including never attended school or other.

Mothers and fathers were also asked “When you were growing up, how much interest did your mother/father show towards your learning and education? This could include helping you with homework or otherwise encouraging your learning”. Responses included: A lot of interest; Some interest; Not much interest; and No interest at all. For both the educational attainment and interest in education questions, parents could also indicate that they did not have a mother or father at the time.

A telephone interview containing these questions was also provided to parents living elsewhere at Wave 5, who were typically fathers living elsewhere following separation or divorce. However, the grandparent interest in education question was only asked in relation to their mother (i.e. paternal grandmother) and not their father (paternal grandfather). In order to keep the analytic sample consistent across analyses, we therefore only include data on fathers living with the grandchild and exclude fathers living elsewhere. We note that the profile of educational attainment of fathers living with the grandchild and those living elsewhere are quite distinct (see Supplementary Table 1). For example, a smaller proportion of fathers living elsewhere had a university qualification, and a larger proportion did not complete Year 12 than fathers living with the grandchild. Despite this difference, the educational profiles of the parents of fathers living with the grandchild and those living elsewhere are more similar (see Supplementary Table 2). As discussed later, the exclusion of parents living elsewhere is recognized as a limitation of the study, however, additional analyses (not reported) show that when PLE data are included we find that the association between grandparent educational attainment and grandchildren’s achievement is very similar, and we would reach the same substantive conclusions with or without including data on fathers living elsewhere.

3.3.2 Educational attainment of mothers and fathers

Across all waves mothers and fathers were asked questions pertaining to their educational attainment. Responses to these questions were then combined to derive the following categories of highest educational attainment: Less than year 12; Less than year 12 with a post-school qualification; Year 12 only; Year 12 with a post-school qualification; and

Year 12, with a bachelor degree or higher. Educational attainment was taken as of Wave 5 to correspond with the collection of information on grandparent education.

3.3.5 Grandchildren's academic achievement

Academic achievement was assessed using test scores from the National Program of Literacy and Numeracy (NAPLAN), which were linked to the LSAC dataset for families who consented to data linkage at Wave 3 and 4. The NAPLAN is a suite of standardized tests of numeracy, reading, spelling and writing, and has been administered to all Australian students in Years 3, 5, 7 and 9 each year since 2008. Tests were administered on the same day across the country towards the end of May, which is close to the end of the first semester. The scores in each learning domain were standardized and scaled to compare the performance of children and schools over time. As of Wave 6, NAPLAN data across Years 3, 5, 7 and 9 were available for most, but not all, of K-cohort children, and Year 3 and 5 for the B-cohort. For this study, we limited analysis to the numeracy and reading scores from the Year 3 assessments from each cohort in order to pool data across the cohorts and maximize the sample size. All regression analyses were adjusted for differences between the cohorts. For the B-cohort, the Year 3 scores correspond approximately with the age of grandchildren at Wave 5 (8–9 years), and at Wave 3 for the K-cohort. Of the 4,400 grandchildren whose father provided education information on grandparents, 3,523 (80%) also had linked Year 3 assessment data available.

3.4 Statistical analysis

SAS 9.4 (SAS Institute Inc., 2002-2012) was used for all analyses. Survey weights available with the dataset were used in all analyses to adjust for non-response and adjustments were made to account for the complex survey design and sample clustering. We first use cross-tabs to examine how the educational attainment of mothers and fathers vary according to the educational attainment of grandmothers and grandfathers, and similarly how educational attainment varies by the level of interest that grandparents showed in the education of mothers and fathers. We then used multinomial logistic regression to estimate the odds of mothers and fathers either completing Year 12, or obtaining a university qualification (relative to not completing Year 12) according to grandparent interest and education, and how these odds ratios vary by *combinations* of grandparent interest and

education (e.g. for grandparents with lower levels of education but who showed a lot of interest). For continuous outcomes (e.g. grandchildren's numeracy and reading scores) we used multivariate linear regression. In all models we did not include controls for other covariates such as parent income or occupation, as these variables will also be influenced by grandparent education and will therefore understate the role that grandparent education has on parent education, and in turn, on grandchildren's achievement. In our final model we assessed how combinations of educational attainment in families predict academic achievement for study children at age 8–9 years.

4. Results

4.1 Links between grandparent and parent education

Table 2 provides both the highest educational attainment of grandparents, along with the educational attainment of mothers and fathers according to the educational attainment of maternal and paternal grandmothers and grandfathers. Table 2 shows that a higher proportion of grandfathers than grandmothers achieved a university qualification (~15% vs 8%) or a post-school qualification (~30% vs 16-19%). Conversely a higher proportion of grandmothers than grandfathers did not progress beyond Year 10 (27-29% vs 16%). These figures also show a substantial increase in the proportion of women achieving a university qualification in one generation, from 8% of grandmothers, to 30% of mothers of the study child. For fathers, this increased from 15% of grandfathers to 35% of fathers. A substantially higher proportion of mothers and fathers had completed a bachelor degree if grandmothers or grandfathers also had a university qualification (over half) as compared to grandparents with lower education levels. In contrast, less than one quarter of mothers and fathers had attained a bachelor degree where grandmothers or grandfathers had not progressed beyond Year 10.

Table 3 provides the highest education level for mothers and fathers according to the level of interest that grandparents showed in the education of the parents while they were growing up. A higher proportion of both mothers and fathers reported that grandmothers showed 'a lot' of interest in their education growing up than did the grandfathers (53% vs 38% for mothers, and 47% vs 30% for fathers). Higher levels of grandparent interest in education were clearly linked with the higher educational attainment of parents. For example, 35% of mothers had completed a bachelor degree where grandmothers had shown a lot of interest in their education, compared to just 11% where grandmothers had shown no interest

at all. The proportion of mothers and fathers who did not complete Year 12 or any other further education was 2–3 times higher when grandparents showed no interest compared to when they showed a lot of interest. We note that the level of interest that grandparents showed in education was also strongly tied to their own educational attainment, and these figures are provided in Supplementary Table 3.

Table 2. Highest education level of study child's mother and father, by highest education level of grandmother and grandfather.

Highest Education Level	Grandmothers						Grandfathers					
	Uni. qual.	Post-school qual.	Year 11/12	Year 10	Year 9 or less	Total	Uni. qual.	Post-school qual.	Year 11/12	Year 10	Year 9 or less	Total
Mothers												
N	643	1,405	1,310	2,050	1,891	7299	1,111	2,134	873	1,173	1,730	7,021
(%)	(8.2)	(17.5)	(16.5)	(26.8)	(30.1)	(100.0)	(14.6)	(29.7)	(12.5)	(16.3)	(26.9)	(100.0)
Less than Year 12	5.6	7.6	12.8	14.5	20.5	14.0	4.3	11.1	10.9	16.8	20.2	13.5
Less than Y12, post-school qual.	14.6	22.9	23.9	34.2	33.1	28.5	14.8	29.8	25.6	30.1	33.7	28.2
Year 12	5.5	6.3	9.8	9.8	8.3	8.4	7.3	8.2	10.3	10.2	7.8	8.5
Year 12 with post-school qual.	17.1	23.1	22.7	18.5	17.4	19.6	17.8	21.5	21.1	18.7	18.6	19.7
Year 12 with bachelor degree	57.1	40.1	30.8	23.0	20.8	29.5	55.8	29.5	32.1	24.2	20.0	30.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Fathers												
N	392	811	850	1,305	1,042	4,400	681	1,430	541	721	952	4,325
(%)	(8.4)	(17.3)	(18.8)	(29.5)	(26.0)	(100.0)	(14.7)	(32.7)	(12.3)	(16.5)	(23.8)	(100.0)
Less than Year 12	4.2	4.4	8.5	10.2	14.3	9.5	2.5	5.6	8.3	11.5	15.8	8.9
Less than Y12, post-school qual.	13.9	21.7	23.8	37.8	33.5	29.3	10.2	33.7	18.7	38.2	33.8	29.1
Year 12	4.5	6.9	10.1	6.6	8.1	7.5	6.5	6.1	10.5	8.1	8.7	7.7
Year 12 with post-school qual.	17.4	19.8	23.0	21.1	18.5	20.2	18.1	21.9	26.4	18.1	17.9	20.3
Year 12 with bachelor degree	60.0	47.1	34.6	24.3	25.6	33.5	62.7	32.6	36.2	24.2	23.7	34.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3. Highest education level of study child's mother and father, by grandparent interest in education.

Highest Education Level	Grandmothers					Grandfathers				
	A lot of interest	Some interest	Not much interest	No interest at all	Total	A lot of interest	Some interest	Not much interest	No interest at all	Total
Mothers										
N	4,292	2,094	963	393	7,742	2,968	2,370	1,297	847	7,482
(%)	(53.0)	(27.3)	(13.8)	(5.9)	(100.0)	(38.2)	(31.3)	(18.0)	(12.5)	(100.0)
Less than Year 12	12.4	15.8	20.9	24.4	15.2	11.0	14.1	19.0	22.0	15.7
Less than Y12 with post-school qual.	23.8	33.7	36.7	42.9	29.4	22.6	30.3	33.3	40.5	30.4
Year 12	8.6	8.1	8.1	7.4	8.3	8.0	9.1	8.1	8.3	9.0
Year 12 with post-school qual.	20.0	19.7	17.0	14.5	19.2	19.2	20.0	20.4	15.5	20.1
Year 12 with bachelor degree or higher	35.2	22.7	17.2	10.8	27.9	39.2	26.6	19.3	13.7	29.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Fathers										
N	2,295	1,666	680	156	4,797	1,313	1,801	1,151	434	4,699
(%)	(47.4)	(34.8)	(13.7)	(3.5)	(100.0)	(29.9)	(37.9)	(24.7)	(9.5)	(100.0)
Less than Year 12	8.1	10.9	14.4	21.8	10.4	6.6	9.1	12.8	19.6	10.3
Less than Y12 with post-school qual.	26.2	33.6	38.6	38.4	31.0	20.7	32.6	37.2	37.2	30.8
Year 12	7.9	7.4	6.3	6.6	7.5	8.0	8.1	5.8	7.4	7.4
Year 12 with post-school qual.	19.4	20.1	20.6	16.0	19.7	18.7	21.4	21.2	13.2	19.8
Year 12 with bachelor degree or higher	38.4	28.0	20.2	17.2	31.4	46.0	28.9	22.9	22.5	31.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The results of the multinomial logistic regression estimating the odds of mothers and fathers completing Year 12 or a university qualification (relative to not completing Year 12) are provided in Table 4. For mothers, the level of interest of maternal grandmothers was not significantly associated with increased odds of mothers completing Year 12 or a university qualification when grandparent education was taken into account. Interest in education from maternal grandfathers however was significantly associated with the educational attainment of mothers; the odds of mothers completing Year 12 were 1.4–1.6 times higher, and the odds of completing a university qualification 2.1 to 2.6 times higher where maternal grandfathers had shown some or a lot of interest in mothers' education compared those who showed none.

Table 4 also shows that fathers were 1.8 times as likely to have obtained a university qualification if the paternal grandmother or paternal grandfather had shown a lot of interest in his education as no interest, and 2.2 times as likely to have completed Year 12 if the paternal grandfather had shown a lot of interest as none. A post-school or university qualification among paternal grandmothers was associated with a two-fold increase in the odds of fathers obtaining a university qualification. Fathers were 4.5 times as likely to have a university qualification where paternal grandfathers had the same.

In order to examine the extent of assortative mating in the sample, Table 4 also models the educational attainment of mothers and fathers according to the educational attainment of the grandchild's other grandparent (i.e. paternal grandparents for mothers, and maternal grandparents for fathers). Mothers were 2.6 times more likely to have completed a university qualification if paternal grandfathers had obtained a university qualification. Similarly, fathers were 1.9 times as likely to have completed a university qualification if maternal grandmothers or grandfathers had also completed a university qualification. These results indicate that the human capital that grandparents pass on to their offspring increases not only their offspring's likelihood of attaining high levels of education, but also their likelihood of partnering with a more highly educated person.

Table 4. Multinomial logistic regression results modelling the odds of mothers and fathers completing Year 12 or a university qualification (ref =less than Year 12), by the combination of grandmother and grandfather education level and interest in education.

	Mothers						Fathers					
	Completing Year 12 vs Less than Year 12			University Qualification vs Less than Year 12			Completing Year 12 vs Less than Year 12			University Qualification vs Less than Year 12		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Own parent's background												
Grandmother interest (ref = no interest)												
Not much interest	1.0	0.6-1.8	.954	0.9	0.5-1.8	.842	1.2	0.7-2.3	.483	1.3	0.7-2.3	.397
Some interest	0.9	0.5-1.6	.687	1.0	0.6-1.9	.914	1.2	0.7-2.3	.482	1.7	1.0-3.1	.397
A lot of interest	1.1	0.6-2.1	.646	1.6	0.9-3.1	.117	1.2	0.6-2.3	.572	1.8	1.0-3.3	.042
Grandfather interest (ref = no interest)												
Not much interest	1.1	0.8-1.6	.578	1.2	0.8-1.7	.367	1.4	0.9-2.0	.119	0.8	0.6-1.2	.323
Some interest	1.6	1.1-2.3	.019	2.1	1.4-3.0	<.001	1.4	1.0-2.1	.070	0.9	0.6-1.3	.573
A lot of interest	1.4	0.9-2.1	.099	2.6	1.7-3.8	<.001	2.2	1.4-3.3	<.001	1.8	1.2-2.8	.004
Grandmother education (ref = Y9 or less)												
Year 10	1.1	0.8-1.4	.583	0.9	0.7-1.2	.547	0.9	0.7-1.2	.554	0.7	0.6-0.9	.010
Year 11/12	1.3	1.0-1.8	.067	1.2	0.9-1.7	.174	1.3	1.0-1.8	.064	1.2	0.9-1.6	.226
Post-school	1.4	1.0-1.9	.055	1.7	1.2-2.3	.001	1.6	1.1-2.2	.007	1.9	1.4-2.6	<.001
University qualification	1.5	0.9-2.4	.099	2.3	1.5-3.7	<.001	1.5	0.9-2.4	.130	2.2	1.4-3.4	<.001
Grandfather education (ref = Y9 or less)												
Year 10	0.9	0.7-1.2	.537	1.1	0.8-1.4	.738	1.0	0.7-1.3	.929	1.0	0.7-1.3	.915
Year 11/12	1.2	0.9-1.8	.212	1.4	1.0-1.9	.067	1.9	1.4-2.8	<.001	2.1	1.5-3.0	<.001
Post-school	1.0	0.8-1.3	.832	1.1	0.9-1.5	.307	1.2	0.9-1.5	.310	1.3	1.0-1.7	.035
University qualification	1.8	1.2-2.6	.007	2.7	1.8-4.0	<.001	2.5	1.6-3.8	<.001	4.5	3.0-6.7	<.001
Partner's parent background												
Grandmother education (ref = Y9 or less)												
Year 10	0.9	0.7-1.2	.289	0.7	0.5-0.9	.019	0.7	0.6-1.0	.041	1.0	0.7-1.3	.752
Year 11/12	1.4	1.1-2.0	.020	1.2	0.9-1.7	.239	1.3	0.9-1.8	.127	1.4	1.0-1.9	.038
Post-school	1.1	0.8-1.6	.259	1.3	0.9-1.8	.216	1.0	0.8-1.4	.810	1.2	0.9-1.6	.239
University qualification	1.6	1.0-2.6	.064	1.6	1.0-2.6	.055	1.3	0.9-2.0	.218	1.9	1.3-2.8	.002
Grandfather education (ref = Y9 or less)												
Year 10	1.0	0.8-1.4	.858	1.1	0.8-1.5	.674	1.2	0.9-1.6	.261	1.0	0.7-1.3	.904
Year 11/12	1.2	0.8-1.7	.294	1.4	1.0-1.9	.088	1.6	1.2-2.3	.006	1.8	1.3-2.6	<.001
Post-school	1.2	0.9-1.6	.259	1.2	0.9-1.6	.216	1.0	0.8-1.4	.777	1.1	0.8-1.4	.622
University qualification	1.4	0.9-2.2	.106	2.6	1.7-4.0	<.001	1.2	0.9-1.7	.298	1.9	1.3-2.6	<.001
Cohort (B vs K)	1.4	1.1-1.7	.001	1.5	1.2-1.9	<.001	1.4	1.2-1.7	<.001	1.3	1.0-1.6	.046

To estimate the extent to which showing interest in education could compensate for lower educational attainment in grandparents we derived a 4-level variable for each grandparent describing them as having a) high interest in mother's/father's education and a high level of education, b) high interest and a low level of education, c) low interest and high level of education, and d) low interest and a low level of education. High interest was defined as having showed a lot or some interest in education, where low interest included showing not much interest, or no interest at all. High education was defined as having a university qualification, diploma or certificate or completing Year 12. Low education was defined as not completing Year 12 or any other qualification. Table 5 provides the results of the multinomial logistic regression. Relative to mothers where maternal grandmothers had low interest and low education, mothers were 1.9 times more likely to have completed Year 12, and 3.4 times as likely to have completed a university qualification where maternal grandmothers had high interest and high education. Importantly, mothers where maternal grandmothers had high interest but low education were 1.5 times as likely to complete a university qualification. These results also show that while the combination of high interest and high educational attainment among grandmothers and grandfathers is the strongest predictor of parents obtaining a university qualification, better educational outcomes for parents were also observed where grandparents had low education but showed higher amounts of interest. That is, the interest that grandparents showed in the education of parents was a significant predictor of parents obtaining a university degree irrespective of the educational attainment of grandparents.

4.2 Links between grandparent education and child achievement

Figure 1 provides the mean Year 3 numeracy and reading scores by the educational attainment of each grandparent, and shows that for each grandparent, both numeracy and reading scores were highest where grandparents had a university qualification, and lowest where grandparents had not progressed beyond Year 9. The association for maternal and paternal grandmothers was broadly linear, with lower child achievement scores associated with lower levels of grandmother educational attainment. For grandfathers, the pattern was L-shaped, where achievement scores were substantially higher for children whose maternal or paternal grandfather had a university qualification, with only subtle differences among lower education levels.

Table 6 provides the estimated differences in Year 3 numeracy and reading scores for grandchildren according to grandparent education. For each learning domain, two models are presented. The first estimates achievement outcomes according to the educational attainment of a grandparent, adjusting for the educational attainment of the other grandparents. Model 2 then adjusts for the educational attainment of mothers and fathers. Subtly different patterns were observed for numeracy and reading achievement. For numeracy, and relative to where grandparents had not progressed beyond Year 9, grandchildren whose grandparent (either maternal, paternal, grandmother or grandfather) had a university qualification achieved between 12 and 26 points higher on average. These effects represent effect sizes of between 0.1 (maternal grandmothers) to 0.3 (paternal grandfathers) of a standard deviation. After controlling for parent educational attainment, only university qualifications among paternal grandfathers remained a significant predictor of numeracy achievement. For parent-level education, relative to children whose parent had not completed Year 12 or equivalent, children scored significantly higher on numeracy if their mother had a university qualification, or if their father had completed Year 12 or had a university qualification.

Table 5. Multinomial logistic regression results modelling the odds of mothers and fathers completing Year 12 or a university qualification (ref =less than Year 12), by the combination of grandmother and grandfather education level and interest in education.

	Mothers						Fathers					
	Completing Year 12 vs Less than Year 12			University Qualification vs Less than Year 12			Completing Year 12 vs Less than Year 12			University Qualification vs Less than Year 12		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Grandmother												
High interest higher educ.	1.9	1.5-2.4	<.001	3.4	2.7-4.3	<.001	1.6	1.2-2.1	.003	3.4	2.5-4.5	<.001
High interest lower educ.	1.2	0.9-1.4	.094	1.5	1.2-1.9	<.001	0.9	0.7-1.2	.592	1.4	1.0-1.8	.033
Low interest higher educ.	1.3	0.9-1.8	.238	1.6	1.0-2.4	.041	1.1	0.7-1.9	.674	2.0	1.2-3.3	.005
Low interest lower educ.	Ref			Ref			Ref			Ref		
Grandfather												
High interest higher educ.	1.8	1.4-2.2	<.001	3.5	2.8-4.3	<.001	2.1	1.6-2.7	<.001	2.7	2.1-3.5	<.001
High interest lower educ.	1.4	1.1-1.7	.004	1.8	1.5-2.3	<.001	1.6	1.2-2.1	<.001	1.3	1.0-1.7	.059
Low interest higher educ.	1.2	1.0-1.5	.095	1.4	1.1-1.8	.013	1.6	1.2-2.1	.003	1.4	1.0-1.9	.029
Low interest lower educ.	Ref			Ref			Ref			Ref		
B cohort vs K	1.4	1.2-1.6	<.001	1.4	1.2-1.8	<.001	1.5	1.2-1.8	<.001	1.3	1.0-1.7	.022

Where low interest = no interest/not much; high interest = a lot of interest, some interest. High education for grandparents includes a university qualification, a diploma/certificate or trade or completing year 12 and low education includes less than year 12 post school or university qualification, lower education = Year 12 or less.

Figure 1. Mean value of Year 3 numeracy and reading scores, by educational attainment of maternal and paternal grandmothers and grandfathers.

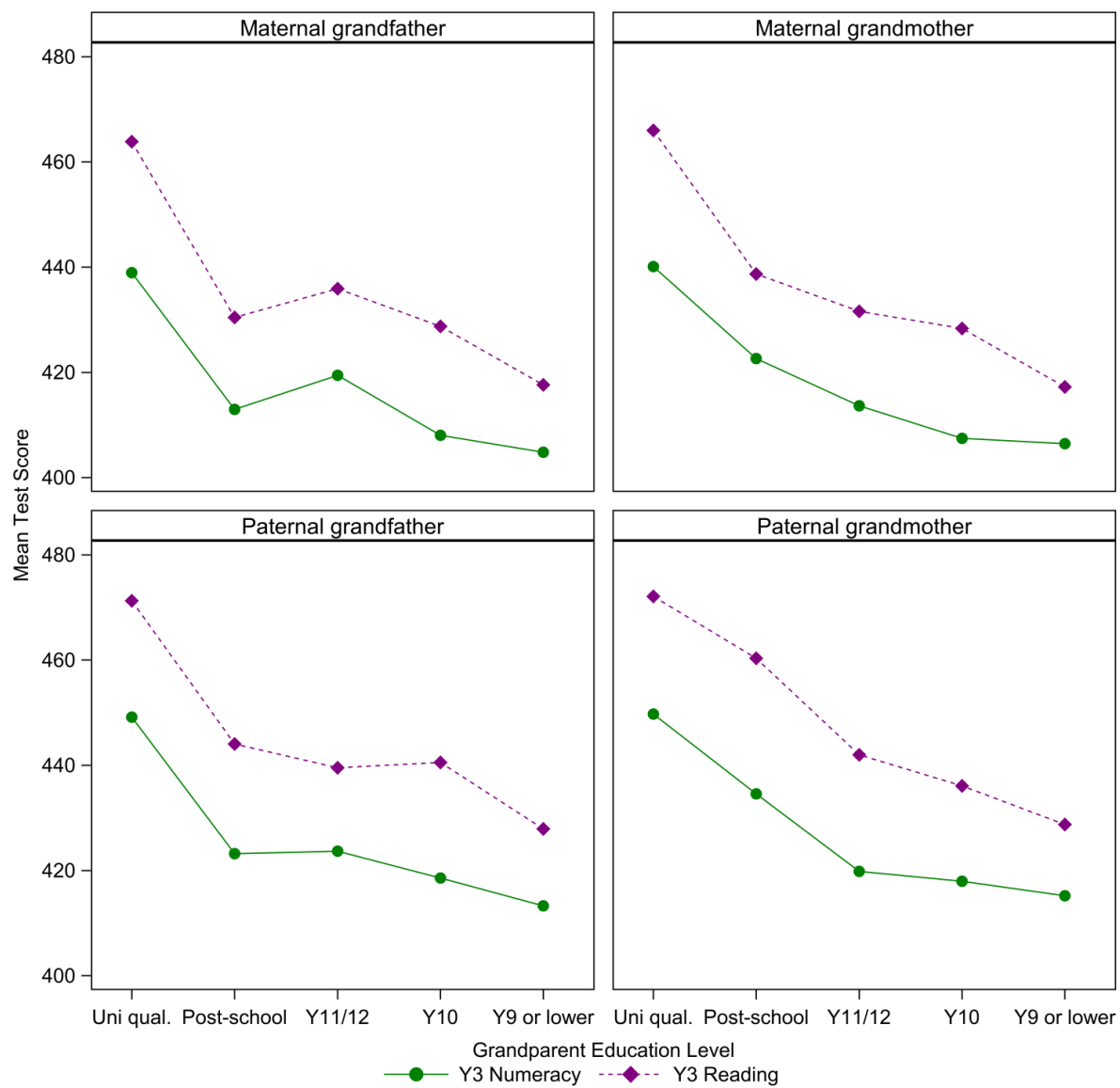


Table 6. Regression analysis modelling numeracy and reading outcomes at Year 3 (age 8–9 years), by grandparent and parent education levels.

	Year 3 Numeracy				Year 3 Reading			
	Model 1		Model 2		Model 1		Model 2	
	Est	p-value	Est	p-value	Est	p-value	Est	p-value
Intercept	405.4	<.001	384.3	<.001	404.4	<.001	395.3	<.001
Maternal grandmother								
Year 9 or less	Ref		Ref		Ref		Ref	
Year 10	0.2	.957	0.3	.941	8.1	.095	8.6	.067
Year 11/12	0.7	.890	-2.1	.643	9.1	.112	6.7	.229
Post-school qualification	7.0	.117	3.4	.455	11.2	.041	8.3	.125
University qualification	11.4	.057	5.9	.315	24.7	<.001	17.6	.011
Maternal grandfather								
Year 9 or less	Ref		Ref		Ref		Ref	
Year 10	-4.3	.354	-4.6	.321	0.0	.994	-0.5	.932
Year 11/12	8.7	.128	5.8	.287	8.7	.168	4.6	.441
Post-school qualification	1.4	.739	1.3	.745	0.9	.862	-0.5	.924
University qualification	16.9	<.001	9.1	.076	16.7	<.001	7.7	.195
Paternal grandmother								
Year 9 or less	Ref		Ref		Ref		Ref	
Year 10	-2.4	.581	0.3	.954	-0.8	.875	2.8	.599
Year 11/12	-3.5	.458	-4.3	.379	3.4	.574	2.8	.632
Post-school qualification	8.1	.092	5.6	.267	19.7	.001	15.1	.011
University qualification	13.7	.030	8.4	.180	21.6	.006	15.3	.043
Paternal grandfather								
Year 9 or less	Ref		Ref		Ref		Ref	
Year 10	4.8	.363	4.3	.376	7.9	.190	8.3	.163
Year 11/12	6.8	.235	2.2	.693	2.5	.698	-3.7	.563
Post-school qualification	8.2	.054	6.3	.136	5.9	.272	2.7	.611
University qualification	25.6	<.001	14.8	.008	22.1	<.001	8.4	.192
Mother's education								
<Year 12			Ref				Ref	
<Year 12, post-school qual.			-1.5	.808			-10.2	.163
Year 12			5.6	.441			5.0	.553
Year 12, post-school qual.			7.4	.221			2.5	.718
Year 12, university qual.			22.7	<.001			19.1	.005
Father's education								
<Year 12			Ref				Ref	
<Year 12, post-school qual.			5.6	.331			19.5	.004
Year 12			15.1	.043			24.2	.004
Year 12, post-school qual.			11.2	.060			22.0	.001
Year 12, university qual.			30.7	<.001			48.9	<.001
Cohort (K vs B)	15.9	<.001	17.3	<.001	-4.7	.161	-2.3	.476
N	2,959				2,923			
Mean score	428.6				448.1			
SD	73.0				85.5			
R-square	0.06		0.11		0.05		0.11	

For reading achievement outcomes, children had higher scores if either grandmother had a post-school or university qualification, or if either grandfather had a university qualification. When controls for parent education were included, the only differences observed were for children who had a maternal grandmother with a university education, or a paternal grandmother with a university education or post-school qualification. The educational attainment of grandfathers was not associated with children's reading achievement scores when parent education was controlled for. Again, children scored 19-points higher in reading if their mother had a university qualification, but 49-points higher in reading if their father had a university qualification, and between 20 and 24 points higher if they had completed Year 12 or had another post-school qualification. In short, the education of grandfathers was associated with numeracy achievement, and the education of grandmothers with reading achievement. The educational attainment of fathers in particular appears important for reading achievement outcomes, net of the contribution of mothers.

Table 7 expands on this analysis by providing an assessment of how the combination of university qualifications in family members is associated with grandchildren's achievement outcomes. For both numeracy and reading achievement, university qualifications were only associated with higher achievement if both the maternal grandmother and grandfather had a university qualification, and no achievement benefit was observed for having only a maternal grandmother or maternal grandfather with a university qualification. Among paternal grandparents, having a paternal grandfather, or both paternal grandparents with a university qualification conferred a 14–19 point advantage relative to having neither paternal grandparent with a university qualification. For reading achievement, grandchildren who had either a paternal grandmother or grandfather, or both, with a university qualification scored 12–17 points higher on average than grandchildren without a paternal grandparent with a university qualification.

Table 7 also shows that having either a mother or a father with a university qualification was associated with significantly higher numeracy and reading achievement scores than children of parents without a university qualification (23–35 points higher, or approximately 0.3 of a standard deviation). Children whose mother and father had both obtained a university qualification scored 44 points higher on numeracy achievement and 53 points higher on reading achievement, the equivalent of approximately 0.6 of a standard deviation. These results suggest a

moderate to large and additive effect of parent university qualifications on children’s numeracy scores.

Table 7. Regression estimates for numeracy and reading achievement in Year 3 (8–9 years), by combinations of university qualifications in grandparents and parents.

	Year 3 Numeracy		Year 3 Reading	
	Est.	p-value	Est.	p-value
Intercept	398.6	<.001	422.9	<.001
Maternal grandparents with a university qual.				
Neither grandparent	Ref		Ref	
Grandmother only	-3.2	.657	1.6	.855
Grandfather only	6.7	.141	5.5	.289
Both grandparents	21.1	<.001	28.0	<.001
Paternal grandparents with a university qual.				
Neither grandparent	Ref		Ref	
Grandmother only	12.5	.078	14.8	.010
Grandfather only	14.2	.004	12.5	.013
Both grandparents	18.6	.005	16.9	.031
Parents with a university qual.				
Neither parent	Ref		Ref	
Mother only	23.4	<.001	26.0	<.001
Father only	26.3	<.001	34.6	<.001
Both parents	44.3	<.001	53.0	<.001
Cohort (K vs B)	15.9	<.001	-4.4	.183
N	2,920		2,923	
Mean score	428.6		448.1	
SD	69.6		81.5	
R-square	0.10		0.10	

5. Discussion

The aim of this study was to examine and describe transfers of human capital in the form of educational attainment across three generations of Australian families. We found that overall, higher levels of grandparent educational attainment were associated not only with higher levels of parent education, but also with numeracy and reading achievement scores among grandchildren at age 8–9 years. Given the intergenerational theories of capital transfers (e.g. Markov processes) and a rapidly expanding literature examining similar relationships, this finding was expected and consistent with previous literature (e.g. Bol & Kalmijn, 2016; Daw & Gaddis, 2016). We also found that the likelihood of mothers or fathers completing Year 12 or equivalent were higher not only if their own parents had a university qualification, but also if their partner or spouse's parents had a university qualification. Again, this is consistent with previous literature demonstrating that individuals are more likely to partner with someone from a background that is similar to themselves (Mare, 1991; Worner, 2006), and also with recent research suggesting that spousal mediation is a key mechanism of transfer of educational advantage from grandparent to grandchild (Daw & Gaddis, 2016). It is also an example of how capital held by grandparents and invested in parents can contribute to better outcomes for subsequent generations through enabling improved choice in potential partners.

Beyond these initial associations though, our results showed three noteworthy findings. First, we demonstrated that the association between grandparent educational attainment and the academic achievement of their grandchildren remained after controlling for the educational attainment of children's mothers and fathers. Previous studies have argued that finding such a 'grandparent effect' independently of parent educational attainment may reflect evidence of a direct influence (e.g. Daw & Gaddis, 2016; Møllegaard & Jæger, 2012). This is not an unreasonable interpretation, given the interactions and potential influences that grandparents may exert on their grandchildren, through direct investments in their grandchild's education, or through cultural forms of educational capital carried in attitudes and expectations. Yet previous research has also shown that as more parent-level characteristics are included in multivariate models, these 'direct' effects diminish (Bol & Kalmijn, 2016). The attenuation of grandparent effects on grandchildren when additional covariates are added is more likely to indicate grandparents with higher levels of educational attainment pass on a range of human capital to their offspring, including attitudes, values, skills and knowledge, which may or may not be

converted by their offspring into higher levels of education, but that influence the way they invest in their own children. The ways in which grandparent education attainment filter through to children's achievement scores, through different types of parent capital, will be addressed in future research that examines how grandparent education and interest in education relates to a variety of human capability indicators in parents, in turn, how these indicators relate to children's academic and social development.

Second, grandparent university education was particularly associated with improved numeracy and literacy in their grandchildren. Importantly, this was gendered – with improved numeracy in grandchildren being associated with grandfather university qualification and improved reading with grandmother university qualification. Including parent education was also telling. Compared with children whose mother or father did not complete Year 12, children whose mother or father had a university qualification had significantly higher numeracy scores, For reading scores, again, higher reading scores were observed only where mothers had a university qualification. However, any level of education higher than Year 12 or higher was associated with larger reading scores among children, and particularly if fathers had a university qualification. The effect having a university qualification on children's reading scores was twice as large for fathers (49 points) than for mothers (19 points).

Third, the largest effect on children's achievement scores occurred in circumstances where maternal grandparents had both attained high levels of education. For example, we found that among maternal grandparents, the grandchildren had significantly higher numeracy and reading scores only when *both* the maternal grandmother and maternal grandfather had a university qualification, net of paternal grandparent and parent education. No educational advantage in grandchildren was observed if, singularly, either the maternal grandmother or the maternal grandfather had a university qualification. For paternal grandparents having either a grandfather or both grandparents with a university qualification was beneficial for numeracy scores, and having either or both grandparents with a university score was beneficial for reading scores. While having either a mother or father with a university qualification was associated with higher reading and numeracy scores, the largest advantage was observed for children who had both a mother and a father with a university qualification, where scores were 0.6 standard deviations higher than children without a university-qualified parent.

Together, these results suggest that educational advantages are concentrated in families, and such a concentration of human capital may contribute further to educational inequalities over the life course. For example, there were few families where a grandmother had a university qualification without the grandfather also having the same, that is, grandparents with higher educational qualification were more likely to partner with each other. They then have children who by adulthood not only have a greater likelihood of a higher qualification, but are also more likely to partner with someone with the same educational background. Our NAPLAN results show that by 8 years of age, the grandchildren in these families with high concentrations of educational capital are already achieving at levels significantly beyond their peers. These results indicate that educational inequality and family formation patterns in Australia contribute to further educational inequalities in subsequent generations. Furthermore, as the overall rate of return in income for a bachelor degree in Australia is 15% for men and 12% in women (Corliss, Lewis, & Daly, 2013), and a bachelor degree is associated with 40 to 60% greater wealth over the life course (Marks, Heady, & Wooden, 2005), the concentration of educational attainment within families is likely to also contribute or be representative of other inequalities in families over the life course.

This study has limitations. For the majority of study children, mothers were primary carers, and provided data on their own education and those of the maternal grandparents during the in-home interview. The data relating to maternal educational history are therefore broadly representative of the LSAC sample. However, data on paternal grandparent education were more limited. While the education levels of secondary carers (mainly fathers) were also collected during the in-home interview, questions concerning the paternal grandparents of residing fathers (either biological, adoptive or step fathers) were collected from residing fathers in a leave-behind survey. Paternal grandparent education data was therefore missing for families where there was no father residing with the child or in families where fathers did not return the leave-behind survey. The questionnaire response bias, and exclusion of data from fathers residing elsewhere, resulted in a sample that only included two-parent families, which on-average display higher levels of education than other parent populations. With the more limited sample used in the current study, our results likely underestimate the true gap in educational advantage bestowed upon children of educated parents. Data that are more representative of the full spectrum of educational histories may reveal more varied associations between grandparent educational

attainment and children's achievement outcomes. Additionally data on grandparent educational attainment relies on secondary and retrospective recall rather than self-report or register data. We would expect that most mothers and fathers could recall with a considerable degree of accuracy the highest educational attainment of their own parents. However, for some respondents, recall of their parent's educational attainment may be less accurate for some parents and others, and recall accuracy may vary across families. The results of this study should be viewed cautiously and with these limitations in mind.

We were also unable to determine the biological relationships between grandparents and grandchildren. If there is biological heritability or genetic transmission of aptitude or cognitive ability contributing to correlations in educational outcomes across generations (Clark, 2014), then this may be considered a limitation of the study. However we note that recent research examined the heterogeneity of the grandparent education effect according to whether grandparents were biologically related to their grandchildren or not (Daw & Gaddis, 2016). The study found only weak evidence that grandparent effects were stronger for biological grandparents than non-biological ones, suggesting that social rather than biological mechanisms may underlie the association between grandparent educational attainment and children's academic achievement.

This current study represents a starting point for examining how the educational resources of grandparents relates to academic achievement outcomes for grandchildren, which to our knowledge has not previously been available for Australian families. In addition to examining the potential mechanisms through which educational attainment is transferred across generations through different forms of human and social capital, future research plans include examining how the effect of grandparent capital on the development of grandchildren varies by the amount of contact that occurs between grandparents and grandchildren. Very few studies have had relevant data to test the hypothesis that grandparent effects should be larger in families where grandparents have more involvement with their grandchildren, and this is one area where the LSAC can contribute to the broader literature. We do note, however, that testing this hypothesis is not straightforward. Most discussion on the topic has considered higher levels of educational attainment as a source of capital that can be passed on or invested in subsequent generations, and that more contact would facilitate such transfers. However, as Pilkauskas and Martinson (2014) show, co-residence with grandparents is more common among less advantaged

families. Similarly, Marks (2007) reported that co-residing with a grandparent is associated with lower achievement outcomes. A stronger hypothesis to investigate may be that the *negative* effect of *low* educational attainment of grandparents on grandchildren is stronger among families with more frequent contact, as those families are more likely to be in situations where support from grandparents is needed.

In conclusion, we have demonstrated that the educational endowments of grandparents have clear implications for the educational success of their own children, and also their grandchildren – a multigenerational transfer of human capital. Our study shows that the transfer of educational resources from grandparent to parent increases the likelihood of a parent partnering with someone from a similar background, which has the effect of concentrating educational resources. The concentration of these resources among more highly educated families then has implications for inequality in educational outcomes among grandchildren. That is, children in families with lower levels of education have fewer human capability resources to draw upon in order to match the educational outcomes of family high in educational capital. These findings have implications for policy makers aiming to reduce socioeconomic inequality in children's achievement. By and large schools are tasked with reducing educational inequalities, for example, through increased funding to disadvantaged schools. These results suggest that compensating for educational inequalities among students and their backgrounds is a significant hurdle for schools to overcome alone, and that substantial support and direction is required in order for schools and other organizations to reduce inequality among students.

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Supplementary Table 1: Educational attainment of fathers living with the study child and those living elsewhere at Wave 5, by cohort.

	B-cohort		K-cohort	
	Living with the study child (n = 3,487)	Living elsewhere (n = 314)	Living with the study child (n = 3,271)	Living elsewhere (n = 277)
	%	%	%	%
<Year 12	12.4	10.7	13.6	15.8
<Year 12, post-school qual.	29.4	35.0	35.8	40.8
Year 12	8.5	17.6	7.9	14.9
Year 12, post-school qual.	21.2	18.6	17.0	15.5
Year 12, university qual.	28.5	18.2	25.7	13.1
Total	100.0	100.0	100.0	100.0

Supplementary Table 2: Educational attainment of the parents of fathers (paternal grandparents) living with the study child and those living elsewhere at Wave 5.

	B-cohort (8–9 years)		K-cohort (12–13 years)	
	Living with the study child (n = 2,269)	Living elsewhere (n = 336)	Living with the study child (n = 2,198)	Living elsewhere (n = 359)
	%	%	%	%
Paternal grandmother				
University qualification	9.1	9.7	7.6	5.0
Post school qualification	18.6	19.3	16.2	18.8
Year 11/12	20.0	20.3	17.4	20.0
Year 10	29.8	30.5	29.0	30.9
Year 9 or less	22.5	20.2	29.7	25.3
Total	100.0	100.0	100.0	100.0
Paternal grandfather				
University qualification	15.6	16.7	13.5	9.1
Post school qualification	35.1	35.7	30.3	33.1
Year 11/12	12.4	9.8	12.1	9.2
Year 10	16.6	18.1	16.4	24.2
Year 9 or less	20.1	19.7	27.6	24.3
Total	100.0	100.0	100.0	100.0

Supplementary Table 3: Level of interest that grandmothers and grandfathers showed towards education, by their educational attainment, for maternal and paternal grandparents.

Interest in Education	Grandmothers						Grandfathers					
	Uni. qual.	Post-school qual.	Year 11/12	Year 10	Year 9 or less	Total	Uni. qual.	Post-school qual.	Year 11/12	Year 10	Year 9 or less	Total
Maternal grandparents												
N	645	1,398	1,303	2,037	1,882	7,265	1,100	2,098	866	1,159	1,701	6,924
(%)	(8.3)	(17.5)	(17.4)	(27.9)	(28.9)	(100.0)	(14.7)	(29.7)	(12.6)	(16.4)	(26.8)	(100.0)
A lot of interest	77.2	62.1	61.5	52.1	40.4	54.2	66.5	40.6	44.1	29.6	26.6	39.3
Some interest	15.0	25.8	26.5	29.7	29.6	27.2	21.3	32.0	35.4	36.7	33.8	32.1
Not much interest	5.8	9.7	9.0	13.4	20.5	13.4	7.8	18.0	13.2	22.0	23.2	17.9
No interest at all	2.0	2.4	3.0	4.7	9.5	5.2	4.4	9.4	7.3	11.7	16.4	10.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Paternal grandparents												
N	394	820	853	1,316	1,045	4,428	680	1,424	540	718	949	4,311
(%)	(8.4)	(17.4)	(18.7)	(29.6)	(26.0)	(100.0)	(14.7)	(32.7)	(12.3)	(16.5)	(23.8)	(100.0)
A lot of interest	76.8	57.9	51.4	46.1	34.5	48.7	54.2	28.2	30.3	21.7	20.0	29.3
Some interest	18.9	32.3	36.9	36.7	36.4	34.4	30.6	40.9	43.3	40.2	34.6	38.1
Not much interest	3.3	9.0	10.3	14.3	22.0	13.7	12.9	23.9	20.1	27.5	32.4	24.4
No interest at all	1.1	0.8	1.3	3.0	7.1	3.2	2.3	7.0	6.3	10.7	13.0	8.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0