

Is the Link Between Intelligence and Age at First Intercourse Causal or Correlational?

A Cross-Generational Sibling Comparison Design Using the NLSY

Abstract

Halpern *et al.* (2000) published a study based on early Add Health data with the provocative title “Smart Teens Don’t Have Sex (or Kiss Much Either).” Several following papers reported the same result, a positive correlation between the intelligence of adolescent girls and age at first intercourse (AFI). However, the causal mechanism has not been carefully investigated. Harden and Mendle (2011) used Add Health data within a biometrical design and found that the relationship between intelligence and AFI was fully accounted for by shared environmental differences, suggesting at least the location of the causal mechanism - the part of the household environment shared by siblings that influences both child intelligence and AFI. In this study, we use an intergenerational sibling comparison design to investigate the causal link between intelligence and AFI, using the National Longitudinal Survey of Youth 1979 and the NLSY-Children/Young Adult data. We measured maternal IQ using the AFQT, child IQ using PPVT, PIAT, and Digit Span, and AFI (using respondent self-report). Our analytic method used Kenny’s (2001) reciprocal standard dyad model. This model supported analyses treating the data as only between-family data (as in past studies), and also allowed us to use within-family comparisons. These included two forms, first a comparison of offspring of mothers in relation to maternal IQ, then a comparison of offspring themselves in terms of offspring IQ.

When we evaluated the relationship between maternal/child intelligence and AFI, using a between-family design, we replicated earlier results. When we use a within-family design and compare offspring of sisters, and then compare the offspring themselves, the relationship between maternal/child intelligence and AFI virtually disappears. The finding is robust across gender and age. These results suggest that the cause of the intelligence-AFI link is not intelligence per se, but rather differences between families (parental education, SES, *etc*) that correlate with family-level (but not individual-level) intelligence.

Keywords: Age at first intercourse; Cross-sectional Data; Discordant Sibling Design; Intelligence; Quasi-Experimental; Siblings

Is the Link Between Intelligence and Age at First Intercourse Causal or Correlational?

A Cross-Generational Sibling Comparison Design Using the NLSY

Teenage sexual activity has interested academics in demography and psychology for many years (Brooks-Gunn & Furstenberg, 1989; Kinsey, Pomeroy, & Martin, 1948; Santelli, Lindberg, Abma, McNeely, & Resnick, 2000). Anecdotal evidence from the popular media, (*e.g.*, MTV's reality television franchise, *16 and Pregnant*), and academic research converge to support a relatively consistent secular decline in age at first intercourse (AFI; see Bozon, 2003; Finer, 2007; Kann et al., 2014). Early AFI is associated with downstream consequences, including lower educational attainment (Harden, 2012; Spriggs & Halpern, 2008; Wellings et al., 2001), failure to meet education and career goals (Halpern, Joyner, Udry, & Suchindran, 2000), increased risk of teenage pregnancy (Leitenberg & Saltzman, 2000; Wellings et al., 2001), and increased rates of sexually transmitted infections (STIs; Kaestle, Halpern, Miller, & Ford, 2005). Moreover, beyond the obvious benefit of avoiding those negative outcomes, delaying AFI is associated with greater relationship satisfaction, perception of increased attractiveness, and higher household income (Harden, 2012). Because many of the negative consequences above are severe and long-reaching, it is important to identify the causal mechanisms associated with early AFI. One potential factor exerting causal influence on AFI is intelligence.

Higher levels of intelligence are associated with delaying first intercourse (Halpern et al., 2000; Mott, 1983; Paul, Fitzjohn, Herbison, & Dickson, 2000; Woodward, Fergusson, & Horwood, 2001), and also with delay of less-intimate sexual involvement (Halpern et al., 2000). Specifically, intelligent individuals may delay intercourse to “safeguard” their futures (Kirby, 2002b; Manlove, 1998; Raffaelli & Crockett, 2003). They perceive the risks associated with early intercourse, (*e.g.*, pregnancy, STIs) to have life- and career-shattering outcomes (Halpern et al., 2000; Harden & Mendle, 2011). Although the link between intelligence and AFI has face validity, and has been confidently asserted (or often implied) as a causal link, a fundamental confound exists in most past research that limits our ability to infer causality.

Virtually all of the AFI-intelligence literature has used between-family designs. In analysis of data from such designs, a number of genetic and environmental influences, such as education and maternal intelligence are confounded (D’Onofrio, Lahey, Turkheimer, & Lichtenstein, 2013; Harden, 2014; Lahey & D’Onofrio, 2010; ?). By ignoring such confounds, the source of variance is ambiguous, and researchers that attribute the source to specific between- or within-family sources risk misattributions of causality (Rowe & Rodgers, 1997; ?). There is the potential for this type of confound in virtually all past research on the link between intelligence and AFI (Harden & Mendle, 2011; Harden, 2014; Plomin & Spinath, 2004; Rodgers, Rowe, & Buster, 1999; Rodgers, Rowe, & May, 1994). Thus, we need to critically evaluate whether intelligence has a causal influence on AFI or is rather a theoretically attractive confound. To resolve some of these methodological challenges, we use design innovations that emerge from the excellent cross-generational and longitudinal structure of the National Longitudinal Survey of Youth (NLSY; we use both the original NLSY79 survey and the NLSY-Children survey, described below).

Cause or Confound?

There are numerous theories that address the motivations for adolescents’ initiation of first intercourse (see Rodgers, 1996 or Buhi & Goodson, 2007 for reviews), and even more specific precursors to first intercourse (Buhi & Goodson, 2007; D’Onofrio & Lahey, 2010; Kirby, 2002a; B. C. Miller et al., 1997; Santelli & Beilenson, 1992). Many of these theories emphasize biology/genetics, as adolescent pubertal development (and associated hormone changes) drives the onset of sexual behavior (W. B. Miller et al., 1999; Udry, 1979, 1994). Other theoretical frameworks use social/environmental processes to explain developing sexual involvement in adolescence, such as Social Learning (DiBlasio & Benda, 1990; Hogben & Byrne, 1998), where social norms affect the likelihood of early sexual behavior; or Social Control theory (Hirschi, 2002), where societal and cultural influences reduce the likelihood that individuals will act on their natural tendency toward sexual involvement. Under these environmental theories the

underlying biology is typically ignored (*e.g.*, Social Control theory), whereas under many of the biological/genetic theories, the environmental components are often ignored.

However, numerous articles have also advocated integrative models (See Harden, Mendle, Hill, Turkheimer, & Emery, 2008; Harden, 2014; Udry, 1995). The integrative Biopsychosocial Model acknowledges both genetic and environmental contributions to human behavior (Engel, 1977; Petersen, 1987; Rodgers et al., 1999). Indeed, biology, psychology, and society/culture jointly influence adolescents' decisions to engage in sexual intercourse (Meschke, Zweig, Barber, & Eccles, 2000; Zimmer-Gembeck & Helfand, 2008).

Intelligence as a Cause

The short-term risks of early AFI are primarily negative, whereas the rewards for delay are primarily positive. These consequences extend into adulthood – early AFI has been related to adult delinquency (Harden et al., 2008), anti-social behavior, and substance abuse (Boislard & Poulin, 2011), whereas those with delayed AFI have higher household incomes in adulthood (Harden, 2012). It is intuitively appealing to believe that intelligent individuals are more likely to observe this potential risk-reward trade off, and through volition act upon such observations by delaying first intercourse. Accordingly, intelligent individuals perceive the consequences of early AFI to negatively influence their careers (Halpern et al., 2000; Harden & Mendle, 2011).

Indeed, most of the literature has contributed to the expectation that intelligence is causally connected to AFI. Those with higher educational goals delay their first intercourse (Boislard & Poulin, 2011; Schvaneveldt, Miller, Berry, & Lee, 2001), whereas those who engaged in early sexual intercourse reduced their educational goals compared to earlier higher goals (Schvaneveldt et al., 2001). Beyond academic goals, those with a greater affinity for risk and those who perceive benefits from teen-pregnancy are more likely to engage in risky sexual activities (Raffaelli & Crockett, 2003). A greater understanding of the risks associated with sexual intercourse, such as HIV transmission,

is also associated with delayed AFI (C. Mathews et al., 2009).

Smarter adolescents are more likely to report delayed intercourse (Halpern et al., 2000; Mott, 1983; Paul et al., 2000; Woodward et al., 2001). Besides delaying first intercourse, smarter individuals appear to postpone all sexual/romantic activity (Halpern et al., 2000). Such blanket delays may be a proactive attempt to avoid “gateway” activities that might lead to intercourse. Thus, many researchers have concluded that “[h]igher intelligence operates as a protective factor against early sexual activity during adolescence, and lower intelligence, to a point, is a risk factor.” (Halpern et al., 2000, p. 213).

However, Halpern et al. (2000) and many of the other studies we have referenced (e.g., C. Mathews et al., 2009; B. C. Miller et al., 1997; Paul et al., 2000) used between-family, typically cross-sectional, designs. Such designs cannot logically distinguish between processes that act to create differences between families and processes that create differences among family members (Lahey & D’Onofrio, 2010; ?). Thus the previous studies do not provide conclusive evidence that intelligence is the causal influence behind the AFI-intelligence relationship. Logically, other alternatives are that AFI has a causal link to intelligence (which is unlikely, for the obvious theoretical reasons, including that a child’s intelligence precedes AFI in time) or that other confounds cause these two outcomes to correlate, but not causally. There are dozens, perhaps hundreds, of such confounds that can logically contend to explain the link between child intelligence and AFI; we review those confounds in the next section.

Intelligence as a Confound

An equally valid set of explanations exist in which intelligence is not the causal factor behind the AFI-intelligence relationship, but rather one of dozens of correlated potentially explanatory processes. Instead, various confounds including family-level selection effects, or third variables at the individual or family level could be causing the relationship. Between-family influences such as SES and maternal intelligence could drive the relationship. Socioeconomic status is associated with the onset of first

intercourse (Lammers, Ireland, Resnick, & Blum, 2000), explains many of the negative consequences linked with teenage pregnancy

Indeed many such findings that link intelligence with various outcomes are quite possibly the result of misattributing between-family confounds to individual-level and within-family causes. The relationship between birth order and intelligence is a classic example of this misattribution (See Damian & Roberts, 2015; ?; ?). We briefly review that research arena here, because it illustrates the same challenge that occurs in studying the link between intelligence and AFI.

Between-family studies that rely on cross-sectional data have consistently found that first born children have higher IQs than later born children (Belmont & Marolla, 1973; Zajonc, 1976). Yet within-family studies have typically found a non-significant relationship (Berbaum & Moreland, 1980; Galbraith, 1982; Retherford & Sewell, 1991; ?; also see Barclay, 2015 and Bjerkedal, Kristensen, Skjeret, & Brevik, 2007 for recent exceptions that have found small, but significant within-family effects in large national studies). Moreover, when designs that can distinguish within- and between-family variance have been conducted, the methodological source of the IQ-birth order effects have emerged from the between-family variance (Black, Devereux, & Salvanes, 2011; Rodgers, 1984; ?; Wichman, Rodgers, & MacCallum, 2006, 2007). Potential causes of this confound include maternal age at first birth, parental IQ, parental education, and SES (Page & Grandon, 1979; Rodgers, 2001; Rodgers et al., 2008, also see (Anastasi, 1956) for an insightful overview, written prior to the IQ-birth order debate.).

In summary, if there is a valid within-family link between intelligence and birth order (which is, definitionally, a within-family variable), it is at one extreme of small magnitude and only detectable in large national datasets, and at the other extreme non-existent (even in large U.S. datasets). Similarly, the link between intelligence and AFI may be mostly or completely spurious. For example, one study found that socioeconomic status is associated with the onset of first intercourse (Lammers et al., 2000), which implicates a between-family process as explanatory of much of the negative consequence early AFI and teenage pregnancy.

Prior Within-Family Analyses

Two past studies have explicitly separated between- and within-family influences on the AFI-intelligence relationship (Harden & Mendle, 2011; Nedelec, Schwartz, Connolly, & Beaver, 2012). Harden and Mendle used 536 same-sex twin pairs from the Add Health Study to “test[] whether relations between intelligence, academic achievement and age at first sex were due to unmeasured genetic and environmental differences between families.” Twins who differed in their intelligence or their academic achievement did not differ in their age at first intercourse. They concluded that “the association between intelligence and age at first sex could be attributed entirely to *unmeasured environmental differences between families*.” (italics added, our own emphasis). Nedelec, Schwartz, Connolly, and Beaver (2012) conducted an exploratory analysis of MZ twin pairs from the same sample used by Harden and Mendle, using intelligence difference scores to predict various social outcomes. They found consistent null results, though their samples were small and their statistical analyses were substantially underpowered.

Current Study, Summary

To summarize, the current study examines the relationship between intelligence and age at first intercourse, using siblings and their children from a multi-generational nationally representative sample, the NLSY. This examination extends the intelligence literature in several key ways. First, we test whether the relationship between intelligence and AFI existed in either or both between- and within-family analyses, using data in which we can explicitly separate those sources of variance. Second, we evaluated the alternative explanation that maternal intelligence influences child AFI, using the cross-generational structure of the NLSY. Third, we replicated our findings using two different age periods. Fourth, we address overlapping question to those studied in Harden and Mendle (2011) and Nedelec *et al.* (2012), using a different data source.

We made the following predictions, based primarily upon Harden & Mendle (2011):

Between Families,

1. Does Generation 2 (*i.e.*, children's) intelligence predict Generation 2 AFI?:

We expect intelligence to be associated with age of first intercourse because there is a sizable body of literature reporting that result (Kirby, 2002b; Manlove, 1998; Raffaelli & Crockett, 2003).

2. Does Generation 1 (*i.e.*, mother's) intelligence predict Generation 2 AFI?: We also expect maternal intelligence to be associated with age of first intercourse because the heritability of intelligence is moderate-to-high (Bouchard, 2004; Devlin, Daniels, & Roeder, 1997). If intelligence does causally influence AFI we would expect that the cross-generational association between AFI and intelligence would be weaker, but existent. However, if the intelligence-AFI relationship is the product of between-family confounds, then we would expect that the cross-generational association between AFI and intelligence would be stronger than the within-generation association because maternal intelligence would be more closely linked with household SES and various parental causes. In other words, maternal intelligence can serve as a proxy for many of the between-family confounds that are of concern in the current study. Comparably sized effects would also be consistent with a between-family confound. Given that Harden & Mendle (2011) found no within-family effect for intelligence, we expect that maternal intelligence will have a comparable or larger effect on between-family AFI than child intelligence.

Within Families,

3. Does Generation 2 intelligence predict Generation 2 AFI?: We do not expect to find within-family differences in intelligence correlating with AFI, given that Harden & Mendle (2011) did not report an effect.

4. Does Generation 1 intelligence predict Generation 2 AFI?: Unknown: it is possible that maternal intelligence will have an effect, as such a link would explain the between-family effects as well as many of the alternative household-level influences.

5. Is the relationship consistent across cross-sectional and within-family designs?: Doubtful, we do not expect the results to be consistent across methods because both

Harden & Mendle (2011) and Meredith (2013) found no within-family effect, whereas the traditional findings from between-family studies find an effect (Kirby, 2002b; Manlove, 1998; Raffaelli & Crockett, 2003). The birth order literature is one example in which apparent causal links mitigate or disappear when variance is properly attributed to within- versus between-family sources.

Method

Research Design

We adapted Kenny and colleagues (2001; 2006) reciprocal standard dyad model to facilitate sibling comparisons. Sibling-based quasi-experimental models are particularly effective for incorporating genetic and environmental design elements (Lahey & D’Onofrio, 2010; ?). Our model uses differences between both pairs of mothers and pairs of adolescents, which provides the measures that explicitly account for within-family variance. Further, within-family differences create a powerful control for virtually all background heterogeneity (variance) associated with both genetic and environmental differences (Lahey & D’Onofrio). We compare individuals from within the family in the context of the following models. First, we predict the difference in AFI, $Y_{i\Delta}$, for a given pair of NLSY-Children, indexed as i , in the following model:

$$Y_{i\Delta} = \beta_0 + \beta_1 \bar{Y}_i + \beta_2 \bar{X}_i + \beta_3 X_{i\Delta} \quad (1)$$

where,

$$Y_{i\Delta} = Y_{i1} - Y_{i2}; X_{i\Delta} = X_{i1} - X_{i2}, \text{ and} \quad (2)$$

$$Y_{i1} = \max(Y_{ij}); Y_{i2} = \min(Y_{ij}) \quad (3)$$

In this model, the relative difference in kin outcomes (Y_{Δ} *e.g.*, AFI) is predicted from the mean level of Y (\bar{Y} , *e.g.* mean AFI), the mean level of X (\bar{X} *e.g.*, intelligence), and the between-kin intelligence difference ($X_{i\Delta}$). The mean levels support causal inference through at least partial control for genes and shared environment in previous generations. Within this model, there is explicit separation of within-family variance (within Y_{Δ} and X_{Δ}), and between-family variance (within \bar{Y} and \bar{X}).

Thus, this model allows us to explicitly untangle between- and within-family influences. If there is a true causal link between intelligence and AFI, then we expect kin differences in intelligence to be significantly associated with kin differences in AFI. If the effect is spurious – only a function of between-family confounds – then we would expect to find no significant relationship between the differences in the outcome with the differences in the predictor.

Sample

The National Longitudinal Survey of Youth 1979 dataset(NLSY79) is based on a nationally representative household probability sample, jointly sponsored by the U.S. Bureau of Labor Statistics and the U.S. Department of Defense. On December 31, 1978, 12,686 adolescents were sampled within a household probability sample from 8,770 households. The initial sample consisted of three subsamples:

- a cross-sectional household probability sample of 6,111 non-institutionalized adolescents residing in the United States on December 31st of 1978;
- a separate over-sampled civilian subsample of 5,295 racial minorities and disadvantaged whites;
- a representative sample of 1,280 youth serving in the U.S. Military on September 30th, 1978.

In the two civilian samples, subjects' birthdates ranged from January 1, 1957 to December 31, 1964, and were between the ages of 14 and 21 on December 31, 1978; military subject's birthdates ranged from January 1, 1957 to December 31, 1961, and were between 17 and 21 years old. Participants were surveyed annually until 1994, and then surveyed biennially to the present. Two waves of planned attrition occurred. After the 1984 interview, all but 201 randomly selected members of the military sample were dropped. After the 1990 interview, all 1,643 disadvantaged whites from the oversample were dropped. Note that because there are no siblings within the military sample, it is irrelevant for the current research, as all military respondents are screened out by the

requirement of having siblings within the sample. More information about the sampling process and the data can be found on the Bureau of Labor Statistics (BLS) website:

<http://www.bls.gov/nls/nlsy79.htm>

In 1986, all biological children of the female NLSY79 participants were surveyed, the first round of the NLSY79 Children and Young Adults (NLSY-Children) survey. Now that childbearing is complete among the NLSY79 females (who were 49 to 57 in the 2014 survey), a total of 11,512 respondents are in the NLSY-Children surveys, which is continuing on a biannual basis. Participants in the NLSY79 will typically be referred to as the Generation 1(Gen1) sample, whereas the NLSY-Children will be referred to as the Generation 2(Gen2) sample.

Tetrads

To conduct our study using the requisite within-family information, we require sister pairs in Generation 1 who both had children. The children of these sisters are cousin-pairs. In the original NLSY79 and NLSY-Children surveys, identification of level of sibling relatedness in the NLSY was primarily inferential. NLSY79 twins, full siblings, half siblings, and adoptive siblings were distinguishable indirectly from respondent and maternal information about birthdates and the biological father(s). NLSY-Children respondents within a given family were all full- or half-siblings, because they were (by design) the biological children of the NLSY79 females. In 2006, both NLSY surveys included explicit indicators of the level of sibling relatedness. Our research team has recently completed a multi-year project to reliably and validly identify the kinship pairs within these two datasets (Rodgers et al., 2016). Sibling and cousin pairs from these kinship links are used in the current study.

Specifically, Mother-Child-Aunt-Nibling (MCAN) tetrads were created using the NLSY Kinship Links (Rodgers et al., 2016) and supporting R package (Beasley et al., 2015). The oldest two female kin (Mother, Aunt) were selected from each NLSY79 household (note that additional female Generation 1 sister pairs from families with three or more sisters – a relatively small number – were excluded). Three tetrad designs

were employed, in which the genders of Generation 2 were the defining feature:

- Mother-Daughter-Aunt-Niece (MDAN) tetrads included the oldest Generation 2 female child from each of the two Generation 1 sisters,
- Mother-Son-Aunt-Nephew (MSAN) tetrads included the oldest Generation 2 male child from each of the Generation 1 sisters, and
- The first two types of tetrads were combined together into Mother-Child-Aunt-Nibling (MCAN) included the first born child from each of the Generation 1 sisters. (Note: “Nibling” refers to an niece or nephew with unspecified gender; compare to “Sibling.”)

Measures

Generation 1 AFI. NLSY-79 subjects indicated their AFI a maximum of three times, in response to questions in 1983, 1984, and 1985. The 1984 and 1985 questions were included to assess those with non-response in 1983, but in fact many female respondents were surveyed multiple times. Further, females were asked for additional related information (Year of First Intercourse, Month of First Intercourse) in 1984 and 1985. The average AFI for women was 18.52 (sd = 2.12; n = 5562); men was 17.16 (sd = 2.36; n = 5640).

We used the repeated questions to estimate the test-retest reliability of self-reported AFI and AFI difference scores. In Table 1, the lower triangle reports the correlations of self-reported AFI across 1983-1985; the diagonal indicates the number of respondents reporting AFI for that year, and the upper triangle indicates the number of respondents that reported AFI for both respective years. The test-retest correlations are moderate to high ($r > .75$) across all viable pairings, suggesting that our subjects are reliably reporting AFI.

Table 1

Gen1 Self-Reported AFI Correlations and Sample Sizes Across 1983-1985

	1983	1984	1985
1983	8432	3765	88
1984	0.86	4516	0
1985	0.76	NA	424

Generation 2 AFI. Over the life-time of the NLSY-Children survey, participants were asked approximately the same questions to assess AFI that their mothers were asked. However, Generation 2 respondents were only asked for AFI information once they had reached age 15 or later. The exact nature of the question varied by administration. Between 1988 and 2000, subjects were asked for age, year, and month of first intercourse. After 2000, subjects were only asked their age.

We calculated NLSY-Children AFI using a multi-step process for three reasons: (1) to account for the diversity of AFI questions across survey administrations, (2) to incorporate multiple reports by the same participant, and (3) to account for the imprecision of AFI reporting (*e.g.*, a subject who reports AFI at 16 could be any age between 16 years and 1 day old through 16 years and 364 days old).

For each survey, we transformed year of first intercourse into an age variable, AFI. If subjects reported both age and year within the same survey and ages were different, we averaged the AFI scores. Across surveys, we identified the earliest possible AFI and the latest possible AFI for each subject. We designated these two AFIs as the Minimum AFI and the Maximum¹ AFI respectively, thus identifying the full range of possible AFIs for each participant. We used this AFI range to calculate the expected value of AFI. Using this method, the average Generation 2 AFI was 16.01 (sd = 2.30; n = 6288).²

After transforming all AFI scores, we recoded impossible AFIs as missing. A score was impossible if the reported AFI exceeded participant's age at time of survey (new $\overline{\text{AFI}} = 15.99$, sd = 2.30, n = 6235). Next, we excluded all AFIs below age 12 (new $\overline{\text{AFI}} = 16.14$, sd = 2.10, n = 6087). Finally we excluded subjects who reported AFI prior to menarche (new $\overline{\text{AFI}} = 16.16$, sd = 2.09, n = 6047). We excluded those below

¹We added 1 year to the Maximum AFI to address the imprecision of self-reported age. The expected value of AFI of any subject does not equal the reported AFI. For example, a subject who reports AFI at 16 could be anywhere from 16 years and 1 day old to 16 years and 364 days old.

²Taking the average of all AFIs (without addressing expected value), results in 15.49 (sd = 2.30; n =

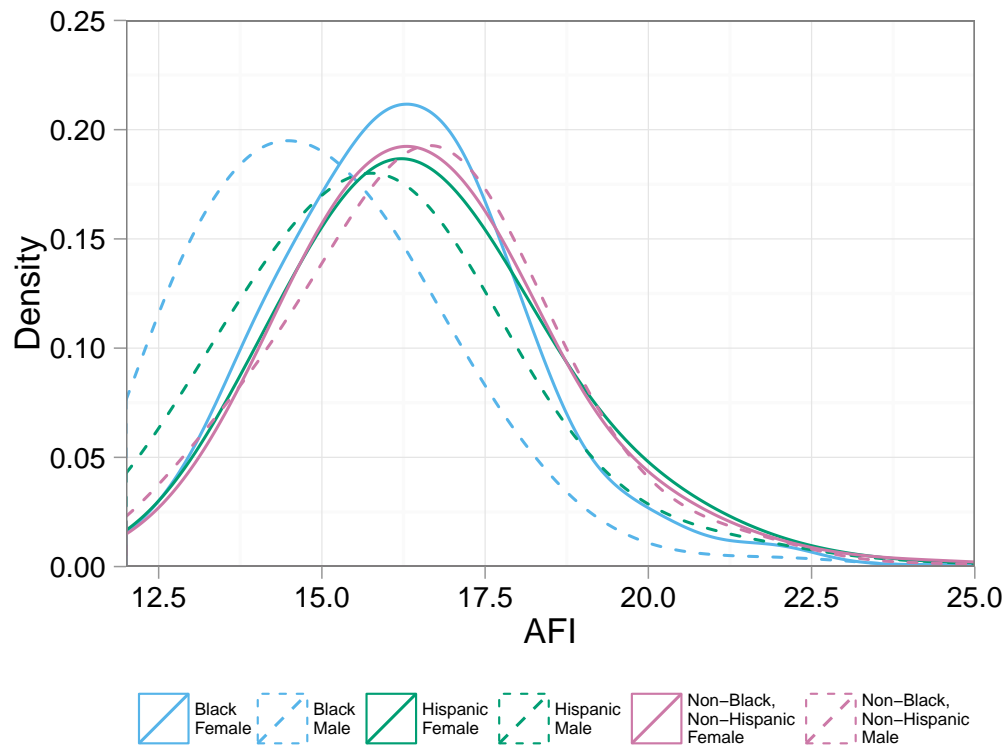
age 12 because those responses likely are the result of misunderstanding, non-consensual sexual activity, or other forms of unreliability. We excluded those with pre-menarchal AFI because we were only interested in AFI that could potentially link to reproduction and fertility. AFI varied by gender and race. Most notably, women reported AFIs that were 6 months later than men, and black men reported the lowest AFI (15 yrs) of any race-gender categories. For a complete portrayal of summary statistics, see Table 2 and Figure 1.

Table 2

Gen2 Mean AFI by Gender, Race, and Gender by Race.

	AFI	
	Mean	Sd
Overall	16.16	2.097
Male	15.88	2.152
Female	16.47	1.991
Hispanic	16.22	2.140
Black	15.66	2.012
Non-Black, Non-Hispanic	16.57	2.054
Hispanic Male	15.92	2.163
Black Male	15.04	1.958
Non-Black, Non-Hispanic Male	16.54	2.061
Hispanic Female	16.60	2.050
Black Female	16.26	1.877
Non-Black, Non-Hispanic Female	16.61	2.048

Figure 1. Smoothed Density Plots of AFI by Race and Sex



Generation 1 Intelligence. The Armed Services Vocational Aptitude Battery (ASVAB; Form 8A; Palmer, Hartke, Ree, Welsh, & Valentine, 1988) was administered to Gen1 participants in 1980. The Armed Forces Qualification Test (AFQT) is contained within the ASVAB, and has been used in the US military as a measure of general trainability (Maier & Sims, 1986). It is a composite of four subscales: Arithmetic Reasoning (AR; 30 items), Math Knowledge (MK; 25 items), Paragraph Comprehension (PC; 15 items), and Word Knowledge (WK; 35 items). Other administrations of the pencil and paper ASVAB reveal that all the AFQT subscales have high coefficient α internal consistency ($\alpha_{AR} = .91$; $\alpha_{WK} = .92$; $\alpha_{PC} = .81$; $\alpha_{MK} = .87$; Kass, Mitchell, Grafton, & Wing, 1982). Reported reliability of the overall AFQT (version 8A) ranges from .87 to .93 (Palmer et al., 1988).

Methods of calculating the AFQT have varied throughout the ASVAB's administrative lifetime (Mayberry & Hiatt, 1992). For pencil and paper administrations, standard scores were created for each of the subscale scores ($\bar{x} = 50$, sd

= 10), and then combined into a standard score. Then, the AFQT standard score is derived from the following formula:

$$\text{AFQT} = \text{AR} + \text{MK} + 2\text{VE}, \quad (4)$$

$$\text{where, } \text{VE} = \text{PC} + \text{WK}. \quad (5)$$

Many researchers have used the AFQT standard score as a proxy for general intelligence (g) (Herrnstein & Murray, 1994; ?). Indeed, the U.S. military has found that the AFQT correlated 0.8 with the Wechsler Adult Intelligence Scale (WAIS; McGrevy, Knouse, & Thompson, 1974). Moreover, the AFQT consistently predicts outcomes traditionally associated with intelligence (Welsh, Kucinkas, & Curran, 1990), including grades (Wilbourn, Valentine, & Ree, 1984; J. J. Mathews, 1977).

Generation 2 Intelligence. NLSY-Children respondents, beginning at age five and as a consistent part of the survey, complete the following test batteries:

- Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1970):
 - Math Subtest (84 items),
 - Reading Recognition Subtest (84 items),
 - Reading Comprehension Subtest (84 items),
- The Peabody Picture Vocabulary Test-Revised (PPVT-R; Form L; Dunn & Dunn, 1981; 175 items), and
- Digit Span Subscale of the Wechsler Intelligence Scales for Children-Revised (Digit Span; Wechsler, 1974; 28 items).

The standard scores of the PPVT-R, PIATs, and Digit Span are considered valid and reliable assessments of cognitive ability (Mott & Baker, 1995). However, subjects were surveyed on a biennial basis. Thus we could not use cognitive tests at a fixed age. Instead, we aggregated scores across a 4 year window, and targeted the midpoint between ages 9 and 10. We targeted 9.5 because all cognitive tests were administered within the 8–11 age window, we wanted to maximize the number of subjects with viable

ability scores, and we wanted to ensure temporal precedence by measuring intelligence prior to the occurrence of AFI. In the case of missing subtests, we allowed age 11 standard scores to replace age 9 standard scores, and age 8 standard scores to replace age 10 standard scores. Our replacement strategy ensured that the average age of testing matched the average of our targeted ages. To obtain intellectual ability measures for each NLSY-children respondent, we fit a confirmatory factor analysis model (using Mplus; Muthén & Muthén, 2014) and their robust maximum likelihood estimator option. A single-factor model fit moderately well (RMSEA = .101; CFI = .973; TLI = .946), and we used this model to construct a unidimensional scale score for each respondent. We used factor scores obtained from this model as our measure of NLSY-Children intelligence.

Replicability & Reliability. We repeated our aggregates of Gen2 intelligence, centered at ages 10.5 and 11.5, and replicated all of our analyses. These replications can be found in the Appendices A and B, respectively. The test-retest reliabilities of Gen2 intelligence across our three aggregations is reported in the lower triangle of Table 3. The diagonal indicates the number of respondents with intelligence aggregations for that year, and upper triangle reveal the number of respondents with viable scores for both respective ages. The test-retest correlations are very high ($r > .90$) across all pairings, suggesting that our method captures consistent measures of intelligence across ages.

Table 3

Correlations and Sample Sizes of Gen2 Aggregated Intelligence across Ages 9.5, 10.5, 11.5

	Age 9.5	Age 10.5	Age 11.5
Age 9.5	8254	7974	7669
Age 10.5	0.95	8143	7838
Age 11.5	0.90	0.96	7970

Reliability of Difference Scores

Our design assumes that the difference scores of our measures are reliable. We've reported the test-retest reliability of Gen2 intelligence and Gen1 AFI in earlier sections.

Here, we report the test-retest reliability of the pairwise differences of those measures.

AFI. Comparing sibling differences in AFI as reported in 1983 and 1984 ($n = 783$ pairs) we found a moderate correlation ($r = .76$). The sample of sibling pairs with complete information in 1985 was too small ($n = 12$ pairs) to compare to the other two years. Regardless, sibling differences in self-reported AFI appear satisfactory for research purposes. We note that the common concern with unreliability of difference scores is at least partially mitigated when the separate scores defining the differences are reliable themselves. Because we could not estimate test-retest reliabilities for Generation 2, we calculated the reliability using Lord's equation (1963). Generation 2 Mean AFI difference scores were also moderately reliable ($r = 0.734$) and comparable to Generation 1 sibling differences.

Intelligence. Cousin differences in intelligence as assessed at ages 9.5, 10.5, and 11.5 were correlated using three different linking methods (Mixed, Daughters, Sons). Reliabilities across linking methods was consistent and high (min $r = .86$; max $r = .95$). However, we could not estimate test-retest reliabilities for Generation 1; we calculated the reliability using Lord's equation (1963). The calculated reliability of Generation 1's differences in AFQT was .61, which was only minimally acceptable, and obviously lower than the empirical correlation we derived for cousin differences.

Results

We examined the relationship between AFI and intelligence using two designs: a between-family design, and a within-family design (which also includes between-family variance in the differences between the family means). The results are organized by those two designs. The between-family analyses report the relationships between the within-family average AFI and various measures of ability. The within-family analyses replicate the between-family analyses using within-family difference scores by testing whether differences in AFI can be explained by differences in various measures of ability.

Between-Family Analyses

First, we examined the between-family results. We tested whether the family average of Gen2 AFI could be predicted by the family averages of Gen1 intellectual ability and of Gen2 intellectual ability. We evaluated the influences both independently and simultaneously. All intelligence scores have been standardized by generation ($\bar{g} = 0$, $sd = 1$), prior to averaging by household. AFI scores have been standardized by gender ($\overline{AFI} = 0$, $sd = 1$), prior to averaging by household.

Gen1 Mean Intelligence \rightarrow Gen2 Mean AFI. Gen1 sister averages (NLSY79 mothers) of standardized AFQT scores were used to predict Gen2 averages of gender-standardized AFI. Table 4 displays the results by Gen2 categories. The Mixed model reports the averages of the first born child (both males and females) of each sister ($n = 342$), the Daughters model reports the averages of the first born girls ($n = 264$), and the Sons model reports the averages of the first born sons ($n = 282$). All three models show similar results. A one unit increase in the average standardized intelligence of the children's mothers predicted a statistically significant increase of $\approx .013$ standard deviations in average Gen2 AFI. The adjusted R^2 varied slightly by Gen2 categories (Mixed = .087, Daughters = .097, Sons = .103).

Gen2 Mean Intelligence \rightarrow Gen2 Mean AFI. Gen2 cousin averages of standardized intellectual ability scores were used to predict Gen2 averages of gender-standardized AFI. Table 5 displays the results by Gen2 categories. The Mixed model reports the averages of the first-borns of each of the NLSY79 mothers (sisters) ($n = 344$), the Daughters model reports the averages of the first born girls ($n = 267$), and the Sons model reports the averages of the first born sons ($n = 283$). All three models show similar results. A one unit increase in the average standardized intelligence of the children predicted a statistically significant $\approx .075$ standard deviation increase in average Gen2 AFI. The adjusted R^2 varied slightly by Gen2 categories (Mixed = .014, Daughters = .016, Sons = .009).

Joint Mean Intelligence \rightarrow Gen2 Mean AFI. Results from the Gen1 sister averages of standardized AFQT scores and Gen2 cousin averages of standardized

intellectual ability scores predicting Gen2 averages of gender-standardized AFI are displayed in Table 6. Again, three models based on Gen2 categories are displayed: Mixed ($n = 337$), Daughters($n = 260$), and the Sons($n = 278$). All three models reveal similar results. Gen1 (maternal) intelligence was significantly associated with Gen2 AFI ($p < .01$), while Gen2 (child) intelligence was not significantly associated with Gen2 AFI. A one unit increase in the average standardized intelligence of the children's mothers predicted $\approx .014$ standard deviation increase in average Gen2 AFI. The adjusted R^2 varied slightly by Gen2 categories (Mixed = .086, Daughters = .097, Sons = .100); each was practically identical to the Gen1 Mean Intelligence models.

Moreover, when we broaden our sample to all Mother-Child pairs, we see that the relationship between Gen2 AFI and Gen2 general ability is small ($r = .139$) and smaller than the relationship between Gen2 AFI and Gen1 general ability ($r = .215$; see Figure 2).

Table 4

Gen1 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.012*** (0.008, 0.017)	0.013*** (0.009, 0.018)	0.014*** (0.009, 0.019)
Constant	−0.754*** (−1.010, −0.500)	−0.801*** (−1.090, −0.513)	−0.856*** (−1.140, −0.569)
Sample Size	342	264	282
R ²	0.090	0.101	0.106
Adjusted R ²	0.087	0.097	0.103
Residual Std. Error	0.700 (df = 340)	0.703 (df = 262)	0.691 (df = 280)
F Statistic	33.500*** (df = 1; 340)	29.400*** (df = 1; 262)	33.200*** (df = 1; 280)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 5

Gen2 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean Intel	0.077** (0.014, 0.140)	0.086** (0.013, 0.159)	0.066* (−0.004, 0.135)
Constant	−0.021 (−0.100, 0.057)	−0.020 (−0.109, 0.070)	−0.039 (−0.125, 0.047)
Sample Size	344	267	283
R ²	0.016	0.020	0.012
Adjusted R ²	0.014	0.016	0.009
Residual Std. Error	0.739 (df = 342)	0.744 (df = 265)	0.732 (df = 281)
F Statistic	5.700** (df = 1; 342)	5.320** (df = 1; 265)	3.430* (df = 1; 281)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 6

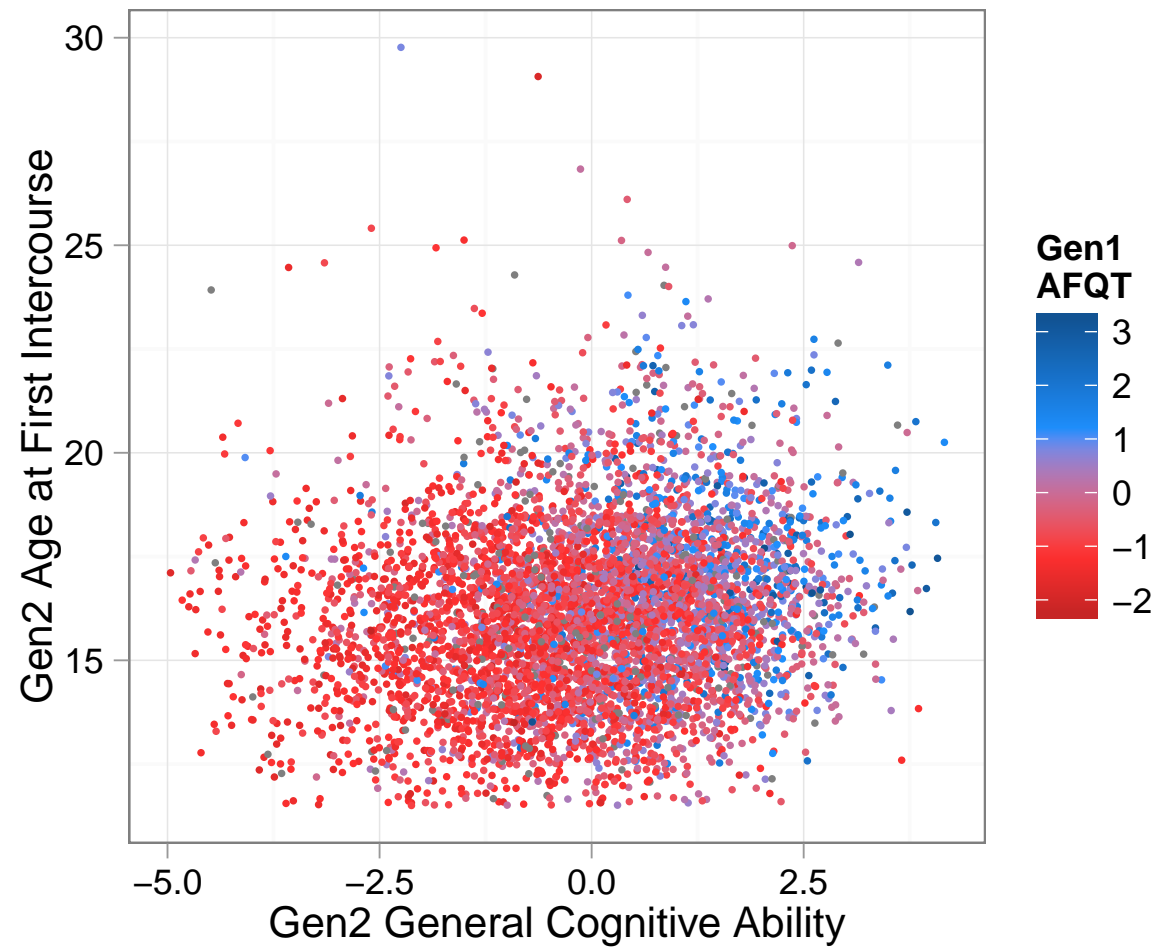
Joint Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.013*** (0.008, 0.017)	0.014*** (0.008, 0.019)	0.015*** (0.009, 0.020)
Gen2 Mean Intel	−0.002 (−0.070, 0.066)	−0.0002 (−0.077, 0.077)	−0.015 (−0.089, 0.060)
Constant	−0.766*** (−1.050, −0.482)	−0.814*** (−1.130, −0.497)	−0.892*** (−1.220, −0.568)
Sample Size	337	260	278
R ²	0.091	0.104	0.107
Adjusted R ²	0.086	0.097	0.100
Residual Std. Error	0.704 (df = 334)	0.706 (df = 257)	0.695 (df = 275)
F Statistic	16.700*** (df = 2; 334)	14.900*** (df = 2; 257)	16.500*** (df = 2; 275)

Note:

*p<0.1; **p<0.05; ***p<0.01

Figure 2. Generation 2: Age at First Intercourse vs. Intelligence



Within-Family Analyses

We replicated the between-family analyses reported in the previous subsection, using within-family difference scores and means. Using the discordant sibling model, we predicted the differences in Generation 2 AFI as a function of differences in intelligence, controlling for means of the outcomes and predictors. We ran three series of models, where we examined the individual and then joint influence of Gen1 intelligence and Gen2 intelligence. Moreover, within each series we included three Generation 2 linking method variants, just as we did in the between family analyses: the Mixed model reports the differences of the first borns of each sister, the Daughters model reports the differences of the first born girls, and the Sons model reports the differences of the first born sons.

Gen1 Intelligence Differences \rightarrow Gen2 AFI Differences. Generation 1 sister differences in standardized AFQT scores were used to predict Generation 2 differences of gender standardized AFI, controlling for Generation 1 sister averages of standardized AFQT scores and Gen2 averages of gender standardized AFI. Table 7 displays the results by Generation 2 linking method. The Mixed model reports the averages and differences of the first borns of each sister ($n = 336$), the Daughters model reports the averages and differences of the first born girls ($n = 258$), and the Sons model reports the averages and differences of the first born sons ($n = 278$). All three models reveal similar results. Generation 2 averages of gender standardized AFI (between-family measures) were significant predictors of Gen2 differences in gender standardized AFI ($p < .01$), across all three linking methods. A one unit increase in the average gender standardized AFI predicted ≈ 0.34 standard deviation increase in average Gen2 AFI difference, controlling for all over variables in the model.

In the Sons model, the Generation 1 sister average of standardized AFQT scores was a significant predictor of differences in Gen2 AFI ($p < .01$). A one unit increase in the average standardized intelligence of the children's mothers predicted $\approx .0083$ decrease in the AFI difference between siblings. All other variables were not significant, including all kin difference variables (the within-family measures). Note that this result

is somewhat anomalous, because it is in the opposite direction to the other results. The adjusted R^2 varied slightly by Generation 2 linking method (Mixed = .066, Daughters = .072, Sons = .106).

Gen2 Intelligence Differences \rightarrow Gen2 AFI Differences. Gen2 cousin differences in standardized intellectual ability scores were used to predict Gen2 differences of gender standardized AFI, controlling for Gen2 cousin averages of standardized ability scores and gender standardized AFI (to account for between-family variance). Table 8 displays the results by Generation 2 categories. The Mixed model reports the averages and differences of the first borns of each sister ($n = 291$), the Daughters model reports the averages and differences of the first born girls ($n = 223$), and the Sons model reports the averages and differences of the first born sons ($n = 238$). All three models reveal similar results. Gen2 averages of gender standardized AFI were significant predictors of Generation 2 differences in gender standardized AFI ($p < .01$), across all three linking methods. A one unit increase in the average gender standardized AFI predicted ≈ 0.38 standard deviation increase in average Gen2 AFI difference, controlling for all over variables in the model.

In the Sons model, the Generation 2 cousin average of standardized ability scores was a significant predictor of differences in Generation 2 AFI ($p < .05$). A one unit increase in the average standardized intelligence of the children predicted $\approx .107$ decrease in the AFI difference between siblings (again, the Sons model result is in the opposite direction to other results). All other variables were not significant, including all kin difference variables. The adjusted R^2 varied slightly by Generation 2 linking method (Mixed = .103, Daughters = .121, Sons = .132).

Moreover, when we replicate this analysis using the larger Gen1 sample of siblings, we find that the between-family relationship of Gen1 AFI and Gen1 general ability is moderate ($r = .291$), but that within the family, the smarter sibling (as illustrated by the blue marginal distributions in Figure 3) were indistinguishable from the less smart sibling (the red marginal distributions). Had there been a within-family effect of intelligence on AFI, the marginal distributions of AFI would not overlap.

Joint Intelligence Differences \rightarrow Gen2 AFI Differences. Generation 1 sister differences in standardized AFQT scores and Gen2 cousin differences in standardized intellectual ability scores were used simultaneously to predict Generation 2 differences of gender standardized AFI, controlling for Generation 1 sister averages of standardized AFQT scores, Gen2 cousin averages of standardized ability scores, and Gen2 cousin averages of gender standardized AFI. Table 9 displays the results by Generation 2 categories. The Mixed model reports the averages and differences of the first borns of each sister ($n = 285$), the Daughters model reports the averages and differences of the first born girls ($n = 217$), and the Sons model reports the averages and differences of the first born sons ($n = 235$). All three models reveal similar results. Gen2 averages of gender standardized AFI were significant predictors of Generation 2 differences in gender standardized AFI ($p < .01$), across all three linking methods. A one unit increase in the average gender standardized AFI predicted ≈ 0.38 standard deviation increase in Generation 2 AFI difference, controlling for all over variables in the model.

All other variables were not significant, including all kin difference variables. The adjusted R^2 varied slightly by Generation 2 linking method (Mixed = .090, Daughters = .105, Sons = .131).

Table 7

Gen1 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.303*** (0.187, 0.419)	0.328*** (0.192, 0.465)	0.376*** (0.251, 0.501)
Gen1 Mean Intel	−0.003 (−0.007, 0.002)	−0.002 (−0.008, 0.004)	−0.008*** (−0.013, −0.003)
Gen1 Dif Intel	0.001 (−0.003, 0.006)	0.001 (−0.005, 0.006)	0.0003 (−0.005, 0.005)
Constant	1.180*** (0.893, 1.470)	1.180*** (0.838, 1.520)	1.500*** (1.180, 1.830)
Sample Size	336	258	278
R ²	0.074	0.083	0.116
Adjusted R ²	0.066	0.072	0.106
Residual Std. Error	0.757 (df = 332)	0.780 (df = 254)	0.734 (df = 274)
F Statistic	8.830*** (df = 3; 332)	7.640*** (df = 3; 254)	12.000*** (df = 3; 274)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 8

Gen2 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.357*** (0.239, 0.475)	0.395*** (0.259, 0.531)	0.398*** (0.269, 0.527)
Gen2 Mean Intel	−0.064 (−0.142, 0.014)	−0.069 (−0.160, 0.021)	−0.107** (−0.193, −0.021)
Gen2 Dif Intel	0.029 (−0.018, 0.075)	0.035 (−0.019, 0.089)	0.009 (−0.041, 0.059)
Constant	1.050*** (0.962, 1.140)	1.070*** (0.970, 1.180)	1.070*** (0.970, 1.160)
Sample Size	291	223	238
R ²	0.112	0.133	0.143
Adjusted R ²	0.103	0.121	0.132
Residual Std. Error	0.769 (df = 287)	0.787 (df = 219)	0.753 (df = 234)
F Statistic	12.100*** (df = 3; 287)	11.200*** (df = 3; 219)	13.000*** (df = 3; 234)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table 9

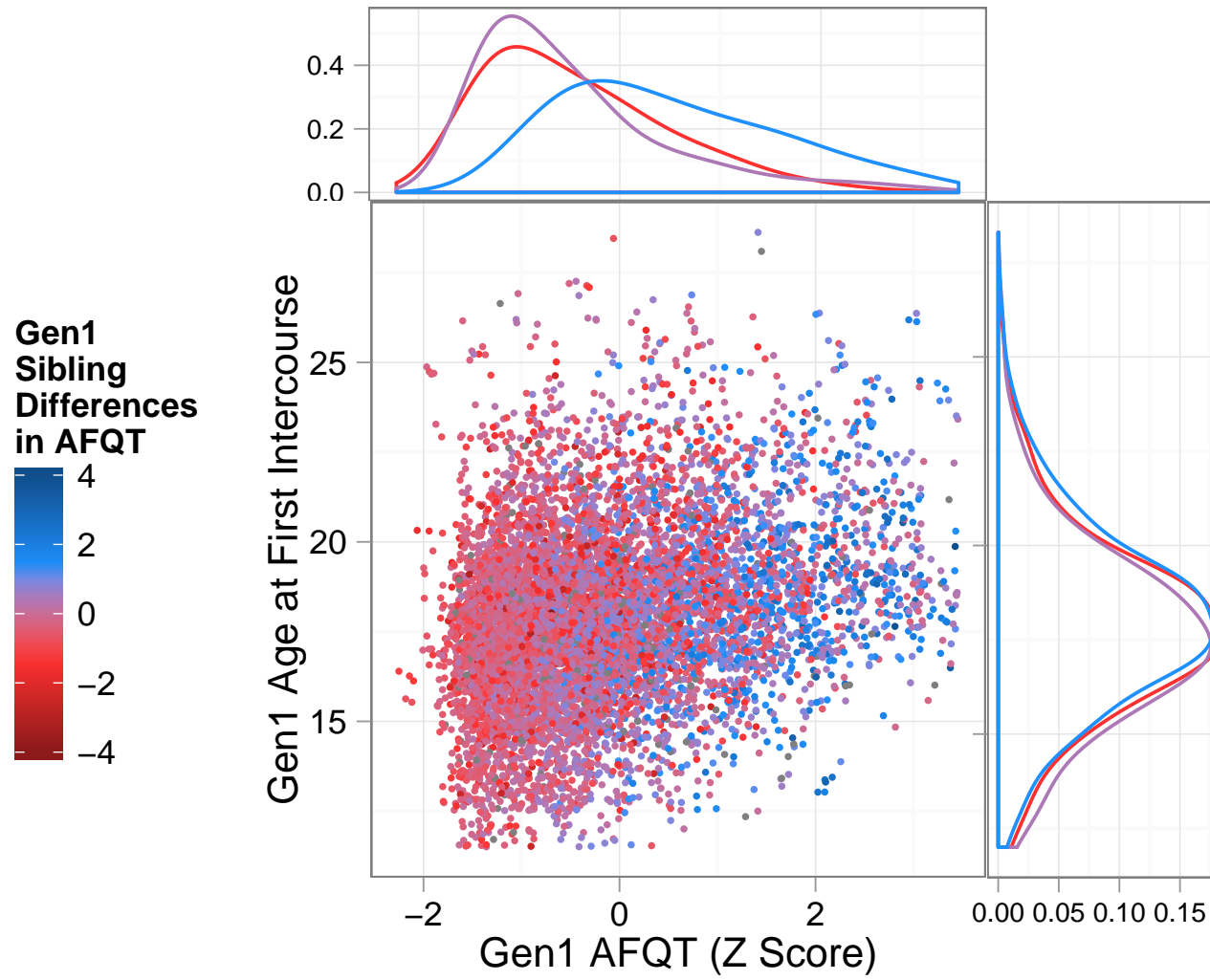
Dif Joint Intelligence → Gen2 Dif AFI

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.345*** (0.221, 0.469)	0.379*** (0.234, 0.524)	0.428*** (0.293, 0.562)
Gen2 Mean Intel	−0.064 (−0.153, 0.024)	−0.071 (−0.174, 0.032)	−0.068 (−0.164, 0.028)
Gen1 Mean Intel	0.001 (−0.005, 0.007)	0.001 (−0.006, 0.008)	−0.005 (−0.012, 0.001)
Gen2 Dif Intel	0.025 (−0.023, 0.073)	0.034 (−0.022, 0.090)	0.007 (−0.044, 0.058)
Gen1 Dif Intel	0.001 (−0.004, 0.006)	−0.001 (−0.007, 0.005)	0.001 (−0.005, 0.006)
Constant	0.999*** (0.642, 1.360)	1.010*** (0.591, 1.430)	1.370*** (0.975, 1.770)
Sample Size	285	217	235
R ²	0.106	0.125	0.150
Adjusted R ²	0.090	0.105	0.131
Residual Std. Error	0.774 (df = 279)	0.795 (df = 211)	0.754 (df = 229)
F Statistic	6.610*** (df = 5; 279)	6.040*** (df = 5; 211)	8.080*** (df = 5; 229)

Note:

*p<0.1; **p<0.05; ***p<0.01

Figure 3. Generation 1: Age at First Intercourse vs. Intelligence



Discussion

This article presents the relationship between AFI and intelligence using two different designs: a between-family design, and a within-family design (that also includes between-family variance within it as well). The between-family design allowed us to replicate results obtained by previous researchers who used a cross-sectional sample. The within-family design allowed us to separate within- and between-family variance, to determine the source of the explanatory processes. The logic of this separation allows us to get much closer to evaluating intelligence differences within the family to address issues of causality. The results revealed a stark contrast between the two methods, and cast doubt on the validity of past causal assertions.

Between- vs. Within-Family Variance

Between-Family Results. Notably, the between-family analyses showed a relationship between intelligence and AFI. Thus, we were able to replicate the findings of various researchers (Halpern et al., 2000; Mott, 1983; Paul et al., 2000; Woodward et al., 2001), and confirm hypotheses 1 and 2. However the relationship between AFI and intelligence was substantially stronger between maternal intelligence and child AFI than between the child's own intelligence and child AFI, suggesting that family-level variables rather than individual-level intelligence is the likely source of the relationship. If the child's own intelligence had been the primary causal influence on AFI we would have expected a considerably weaker cross-generational association between AFI and intelligence. Instead we find that the within-generation association is the weaker effect, suggesting that the child's own AFI is likely derivative of the child's mother's intelligence (or other between-family correlates), which are the more likely causal influence.

Thus, the “new” and alternative interpretation of this finding would be that maternal intelligence or correlates are driving the effect, and that past between-family analyses finding a link between child's intelligence and AFI are likely because child's intelligence is indirectly measuring maternal intelligence/correlates.

There are interpretations that would support the plausibility of this results, including maternal intelligence as a direct causal influence. Smarter mothers might be more effective at encouraging their children to delay intercourse – perhaps by effectively conveying the riskiness of sexual intercourse (Hutchinson, Jemmott, Jemmott, Braverman, & Fong, 2003; C. Mathews et al., 2009). Considering that intelligence is highly heritable (Bouchard, 2004) and thus highly correlated across generations, this alternative explanation would still be consistent with the traditional between family findings, which typically do not control for maternal intelligence (Halpern et al., 2000; Mott, 1983; Paul et al., 2000; Woodward et al., 2001). However, we note that the Harden & Mendle (2011) findings, using biometrically-informed data, implicated the shared environment in this causal process. Our results are entirely consistent with theirs, using a different dataset and a different methodological approach to identify important sources of variance.

Within-Family Results. In the within-family analyses, the effect vanishes for both maternal intelligence and child intelligence. The child of the smarter Generation 1 mother was not more likely to delay intercourse compared to the child of the less-smart Generation 1 mother. Moreover, in spite of our finding that the Generation 1 intelligence was a relatively stronger predictor of Generation 2 AFI, we did not find that differences in Generation 1 intelligence to be associated with differences in Generation 2 AFI.

Concluding Remarks. These results cast doubts on the alternative explanation for the between-family results we posed in the previous paragraph. For, if Generation 1 maternal intelligence was driving the effect as a proximal cause, we would have expected to find a significant within-family link from maternal intelligence to child AFI, which we did not. Rather, we think maternal and child intelligence are indirect measures of many other household features, any one of which may be more proximal as the causal explanation - income, parental education, family interaction. Or, the whole package of these features may stand in for a general environmental factor, a “little e,” which indexes the quality of the home environment, which could be measured as a

composite of parental income, intelligence, education, family interaction.

We interpret these results in relation to two previous findings. First, Rodgers et al. (2008) used Danish twin data, and found that the link from education/cognitive ability to maternal age at first birth (AFB) was entirely accounted for by between-family variance: “variance in AFB emerges from [IQ and education] differences between families, not differences between sisters within the same family” (Rodgers et al., 2008, p. S202). We have exactly the same result in the current study. Second, Harden and Mendle’s (2011) results, obtained using the Add Health data, use intelligence as a predictor and AFI as an outcome, just as we did. Their biometrical finding of meaningful shared environmental variance is the equivalent biometrical result to our finding of only between-family variance. But our design allows us to cast further doubt on the direct and causal influence of maternal intelligence, and leaves the general family environment and other factors correlated with maternal intelligence as the likely causal influences on AFI.

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Appendix A
Age 10.5 Replication

Between-Family Analyses

Table A1

Gen1 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.012*** (0.008, 0.017)	0.013*** (0.009, 0.018)	0.014*** (0.009, 0.019)
Constant	−0.754*** (−1.010, −0.500)	−0.801*** (−1.090, −0.513)	−0.856*** (−1.140, −0.569)
Sample Size	342	264	282
R ²	0.090	0.101	0.106
Adjusted R ²	0.087	0.097	0.103
Residual Std. Error	0.700 (df = 340)	0.703 (df = 262)	0.691 (df = 280)
F Statistic	33.500*** (df = 1; 340)	29.400*** (df = 1; 262)	33.200*** (df = 1; 280)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A2

Gen2 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean Intel	0.098*** (0.039, 0.157)	0.105*** (0.036, 0.173)	0.088*** (0.022, 0.153)
Constant	−0.015 (−0.093, 0.062)	−0.015 (−0.104, 0.074)	−0.031 (−0.117, 0.054)
Sample Size	345	267	283
R ²	0.030	0.033	0.024
Adjusted R ²	0.027	0.029	0.021
Residual Std. Error	0.734 (df = 343)	0.739 (df = 265)	0.728 (df = 281)
F Statistic	10.500*** (df = 1; 343)	8.990*** (df = 1; 265)	6.910*** (df = 1; 281)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A3

Joint Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.012*** (0.007, 0.017)	0.013*** (0.007, 0.018)	0.014*** (0.008, 0.019)
Gen2 Mean Intel	0.021 (−0.046, 0.088)	0.018 (−0.058, 0.094)	0.008 (−0.066, 0.082)
Constant	−0.714*** (−1.010, −0.418)	−0.771*** (−1.100, −0.440)	−0.844*** (−1.180, −0.506)
Sample Size	338	260	278
R ²	0.092	0.103	0.107
Adjusted R ²	0.086	0.096	0.101
Residual Std. Error	0.703 (df = 335)	0.707 (df = 257)	0.695 (df = 275)
F Statistic	16.900*** (df = 2; 335)	14.700*** (df = 2; 257)	16.500*** (df = 2; 275)

Note:

*p<0.1; **p<0.05; ***p<0.01

Within-Family Analyses

Table A4

Gen1 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Difference in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.303*** (0.187, 0.419)	0.328*** (0.192, 0.465)	0.376*** (0.251, 0.501)
Gen1 Mean Intel	−0.003 (−0.007, 0.002)	−0.002 (−0.008, 0.004)	−0.008*** (−0.013, −0.003)
Gen1 Dif Intel	0.001 (−0.003, 0.006)	0.001 (−0.005, 0.006)	0.0003 (−0.005, 0.005)
Constant	1.180*** (0.893, 1.470)	1.180*** (0.838, 1.520)	1.500*** (1.180, 1.830)
Sample Size	336	258	278
R ²	0.074	0.083	0.116
Adjusted R ²	0.066	0.072	0.106
Residual Std. Error	0.757 (df = 332)	0.780 (df = 254)	0.734 (df = 274)
F Statistic	8.830*** (df = 3; 332)	7.640*** (df = 3; 254)	12.000*** (df = 3; 274)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A5

Gen2 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Difference in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.326*** (0.208, 0.444)	0.366*** (0.228, 0.504)	0.357*** (0.227, 0.486)
Gen2 Mean Intel	−0.079** (−0.151, −0.008)	−0.088** (−0.173, −0.003)	−0.111*** (−0.190, −0.032)
Gen2 Dif Intel	0.024 (−0.020, 0.068)	0.023 (−0.029, 0.074)	0.002 (−0.044, 0.048)
Constant	1.040*** (0.951, 1.130)	1.060*** (0.959, 1.170)	1.050*** (0.957, 1.150)
Sample Size	287	219	234
R ²	0.100	0.118	0.125
Adjusted R ²	0.091	0.105	0.114
Residual Std. Error	0.756 (df = 283)	0.778 (df = 215)	0.738 (df = 230)
F Statistic	10.500*** (df = 3; 283)	9.570*** (df = 3; 215)	11.000*** (df = 3; 230)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table A6

Joint Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Difference in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.315*** (0.191, 0.438)	0.347*** (0.202, 0.493)	0.388*** (0.255, 0.521)
Gen2 Mean Intel	−0.077* (−0.161, 0.007)	−0.088* (−0.187, 0.011)	−0.059 (−0.150, 0.032)
Gen1 Mean Intel	0.0002 (−0.006, 0.006)	0.001 (−0.007, 0.008)	−0.007** (−0.013, −0.0001)
Gen2 Dif Intel	0.018 (−0.028, 0.063)	0.021 (−0.033, 0.074)	0.00003 (−0.047, 0.047)
Gen1 Dif Intel	0.002 (−0.004, 0.007)	−0.001 (−0.008, 0.005)	0.002 (−0.004, 0.007)
Constant	1.020*** (0.656, 1.380)	1.020*** (0.597, 1.440)	1.440*** (1.040, 1.840)
Sample Size	282	214	232
R ²	0.094	0.109	0.138
Adjusted R ²	0.077	0.087	0.119
Residual Std. Error	0.759 (df = 276)	0.783 (df = 208)	0.735 (df = 226)
F Statistic	5.710*** (df = 5; 276)	5.080*** (df = 5; 208)	7.260*** (df = 5; 226)

Note:

*p<0.1; **p<0.05; ***p<0.01

Appendix B
Age 11.5 Replication

Between-Family Analyses

Table B1

Gen1 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.012*** (0.008, 0.017)	0.013*** (0.009, 0.018)	0.014*** (0.009, 0.019)
Constant	−0.754*** (−1.010, −0.500)	−0.801*** (−1.090, −0.513)	−0.856*** (−1.140, −0.569)
Sample Size	342	264	282
R ²	0.090	0.101	0.106
Adjusted R ²	0.087	0.097	0.103
Residual Std. Error	0.700 (df = 340)	0.703 (df = 262)	0.691 (df = 280)
F Statistic	33.500*** (df = 1; 340)	29.400*** (df = 1; 262)	33.200*** (df = 1; 280)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table B2

Gen2 Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean Intel	0.104*** (0.044, 0.163)	0.117*** (0.047, 0.187)	0.091*** (0.027, 0.156)
Constant	−0.016 (−0.094, 0.062)	−0.007 (−0.097, 0.083)	−0.035 (−0.121, 0.050)
Sample Size	339	262	278
R ²	0.034	0.040	0.027
Adjusted R ²	0.031	0.036	0.023
Residual Std. Error	0.729 (df = 337)	0.738 (df = 260)	0.721 (df = 276)
F Statistic	11.700*** (df = 1; 337)	10.700*** (df = 1; 260)	7.650*** (df = 1; 276)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table B3

Joint Mean Intelligence → Gen2 Mean AFI

	<i>Dependent variable: Average of Gen2 AFI</i>		
	Mixed	Daughters	Sons
Gen1 Mean Intel	0.012*** (0.007, 0.017)	0.013*** (0.007, 0.018)	0.014*** (0.008, 0.020)
Gen2 Mean Intel	0.010 (−0.060, 0.079)	0.017 (−0.064, 0.099)	−0.006 (−0.081, 0.070)
Constant	−0.722*** (−1.030, −0.416)	−0.751*** (−1.100, −0.401)	−0.861*** (−1.210, −0.511)
Sample Size	333	255	274
R ²	0.087	0.098	0.103
Adjusted R ²	0.082	0.091	0.096
Residual Std. Error	0.705 (df = 330)	0.709 (df = 252)	0.696 (df = 271)
F Statistic	15.800*** (df = 2; 330)	13.800*** (df = 2; 252)	15.600*** (df = 2; 271)

Note:

*p<0.1; **p<0.05; ***p<0.01

Within-Family Analyses

Table B4

Gen1 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.303*** (0.187, 0.419)	0.328*** (0.192, 0.465)	0.376*** (0.251, 0.501)
Gen1 Mean Intel	−0.003 (−0.007, 0.002)	−0.002 (−0.008, 0.004)	−0.008*** (−0.013, −0.003)
Gen1 Dif Intel	0.001 (−0.003, 0.006)	0.001 (−0.005, 0.006)	0.0003 (−0.005, 0.005)
Constant	1.180*** (0.893, 1.470)	1.180*** (0.838, 1.520)	1.500*** (1.180, 1.830)
Sample Size	336	258	278
R ²	0.074	0.083	0.116
Adjusted R ²	0.066	0.072	0.106
Residual Std. Error	0.757 (df = 332)	0.780 (df = 254)	0.734 (df = 274)
F Statistic	8.830*** (df = 3; 332)	7.640*** (df = 3; 254)	12.000*** (df = 3; 274)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table B5

Gen2 Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.344*** (0.225, 0.463)	0.369*** (0.232, 0.506)	0.382*** (0.251, 0.512)
Gen2 Mean Intel	−0.097*** (−0.168, −0.026)	−0.120*** (−0.205, −0.035)	−0.130*** (−0.207, −0.052)
Gen2 Dif Intel	0.037 (−0.007, 0.081)	0.034 (−0.016, 0.084)	0.015 (−0.032, 0.062)
Constant	1.050*** (0.962, 1.140)	1.070*** (0.963, 1.170)	1.080*** (0.979, 1.170)
Sample Size	286	223	230
R ²	0.117	0.131	0.149
Adjusted R ²	0.108	0.119	0.138
Residual Std. Error	0.751 (df = 282)	0.773 (df = 219)	0.734 (df = 226)
F Statistic	12.500*** (df = 3; 282)	11.000*** (df = 3; 219)	13.200*** (df = 3; 226)

Note:

*p<0.1; **p<0.05; ***p<0.01

Table B6

Joint Intelligence Differences → Gen2 AFI Differences

	<i>Dependent variable: Differences in Gen2 Mean AFI</i>		
	Mixed	Daughters	Sons
Gen2 Mean AFI	0.328*** (0.203, 0.452)	0.339*** (0.194, 0.483)	0.417*** (0.282, 0.552)
Gen2 Mean Intel	−0.098** (−0.184, −0.013)	−0.131** (−0.234, −0.029)	−0.071 (−0.163, 0.021)
Gen1 Mean Intel	0.001 (−0.005, 0.007)	0.002 (−0.005, 0.010)	−0.007** (−0.014, −0.0001)
Gen2 Dif Intel	0.034 (−0.011, 0.080)	0.037 (−0.016, 0.089)	0.012 (−0.036, 0.059)
Gen1 Dif Intel	0.002 (−0.004, 0.007)	−0.002 (−0.008, 0.005)	0.001 (−0.004, 0.007)
Constant	0.984*** (0.615, 1.350)	0.925*** (0.489, 1.360)	1.470*** (1.060, 1.890)
Sample Size	278	215	226
R ²	0.112	0.125	0.162
Adjusted R ²	0.096	0.104	0.143
Residual Std. Error	0.751 (df = 272)	0.775 (df = 209)	0.727 (df = 220)
F Statistic	6.860*** (df = 5; 272)	5.970*** (df = 5; 209)	8.500*** (df = 5; 220)

Note:

*p<0.1; **p<0.05; ***p<0.01