The Relationships of Time-Varying Family Structure and Poverty Status to Child Trajectories of Mathematical Achievement

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Questions about how family structure and poverty impact child well-being are not new. Research finds that children who grow up with continuously married biological parents fare better than children who spend time in other family structures on most measures of child well-being and many measures of adult well-being (Amato 2005). Academic achievement, particularly in mathematics (due to structured tracks within schools), is a child outcome that is strongly linked to educational attainment, which is one of the main paths to future economic opportunity (Crosnoe, et al. 2004; Hallinan 2001; Stevenson, et al. 1994). Some research also suggests that economic resources and the parental resources they are correlated with (e.g. available time, quality of parenting, or cognitive stimulation), may explain large portions of the relationships between family structure and children's educational achievement (Pong, et al. 2003; Pong & Ju 2000; McLanahan & Sandefur 1994; McLanahan 1985). Yet, other researchers also find that parental conflict and difficult transitions create an unstable family experience that could explain some of the negative outcomes found for children who do not live with married biological parents (Amato, et al. 1995; McLanahan and Sandefur 1994; Grych and Fincham 1990).

Recent research has shown the importance of separating the effects of cohabiting biological parents and cohabiting stepfamily structures from the more common categories of married biological parents, single-parents, and married stepfamilies when studying child outcomes (Raley, et al. 2005; Brown 2004; Raley & Wildsmith 2004). One such study found that living in a cohabiting stepparent family structure is associated with poorer grades and a higher probability of high school dropout than is living with both biological parents, or with divorced or remarried parents (Raley, et al. 2005). Another

study found that children living with cohabiting biological parents experience more behavioral and emotional problems than children of married biological parents (Brown 2004). Thus, "research that does not distinguish among different forms of unmarried-mother families is likely to assign the negative effects of cohabitation to experience in a single-parent family" (Raley, et al. 2005: 158).

The instability explanation of family structure effects on child well-being tends to be especially salient for explaining negative effects of cohabiting family structures (Raley, et al. 2005; Raley and Wildsmith 2004), because cohabiting unions are unstable; it has been found that only half of cohabiting couples end up getting married (Bumpass and Lu 2000) and that the relationships of the cohabiters that do not get married usually do not last as long as the marriages and remarriages do (Bumpass, et al. 1991). Also, compared to married couples, cohabiting couples generally report poorer relationship quality (Brown and Booth 1996) and have been found to experience a higher likelihood of physical abuse (Magdol, et al.1998). Thus, children of cohabiters are more likely to experience more family transitions (Manning, et al. 2004) and more parental conflict than children born to two married biological parents. Therefore, it is not surprising that some studies find that children living in cohabiting stepfamily structures not only fare worse than children living with two biological parents on educational outcomes, but also fare worse than children in married stepfamily structures and sometimes worse than children in single-mother homes (Raley, et al. 2005; Manning and Lamb 2003; Thomson, et al. 1994).

The covariates of family structure and socioeconomic status have not been examined using methods that allow their effects to vary over time. Therefore, it is

important to explore whether the relationships between economic resources, family structure, and academic achievement differ by age of the child. Some studies have examined the timing of economic resource effects on academic outcomes and found seemingly conflicting results. For example, Duncan, et al. found that family income during early childhood has a greater impact than family income during middle childhood and early adolescence on completed schooling (1998). Yet, Guo found that poverty experienced in adolescence exerts more influence on adolescent achievement test scores than does poverty experienced earlier in life (1998). Therefore, because these findings do not seem to completely agree with each other, it is important to continue seeking an answer to the question of when poverty effects on children's academic outcomes are strongest.

The timing of family structure effects on child outcomes has received a little attention from researchers. One study tested the timing of family structure effects on children's years of completed schooling and non-marital births, but did not separate cohabiting family structures from other types of family structure and found no significant effects of single-mother and stepfamily structures across all age groups (Hill, et al. 2001). Another study examined how family structure effects on school engagement and on emotional and behavioral problems are different during middle childhood (6-11) and adolescence (12-17), and it was one of the first studies of family structure effects on child well-being to separate both cohabiting biological and cohabiting stepfamily structure effects from other family structure effects (Brown 2004). The author found that cohabiting family structure effects on emotional and behavioral problems are not significant during middle childhood, after controlling for parental and economic

resources, while the effect of cohabiting biological parents on school engagement remains significant. In contrast to the pattern found for middle childhood, the author found that the cohabiting family structure effects on emotional and behavioral problems remain significant during adolescence, even after controlling for parental and economic resources, while the effect of cohabiting stepfamilies on school engagement also remains significant. Unfortunately, neither of these two studies examines the effects of family structure on measures of academic achievement. Thus, it remains to be determined whether family structure effects on academic achievement are stronger during early childhood or during later childhood.

We know that both family structure and poverty status are related to children's academic achievement, but we are not yet sure how these two factors work together to influence achievement during different phases of childhood. Therefore, the following research questions will be addressed in this study: (1) How do the covariates of family structure and poverty status each relate to math test score gains, controlling for the other? (2) How do other variables such as race/ethnicity, gender, and characteristics of the mother influence math score gains? (3) How do all these relationships differ at critical time points in children's academic careers?

Data and Sample

This study will use data from the Children of the National Longitudinal Survey of Youth (CNLSY). The respondents in the CNLSY are the biological children of the female respondents of the NLSY-79, which is a nationally representative sample of 12,686 youths who were aged 14 to 22 at the time of their first interview in 1979. Starting in 1986, the children of the female NLSY-79 respondents were interviewed and

given several behavioral and cognitive assessments every two years. The data covers the years of 1986 through 2002, and each survey year contains children between the ages of 0 and 179 months (0-14 years).

The CNLSY administered the Mathematics Assessment of the Peabody Individual Achievement Test (PIAT-M) at each interview to children ages five through fourteen. Therefore, in order to use all the available data, I pooled the data from the nine available interview waves into the maximum total number of possible math assessment time points for any one child. Thus, there can be a maximum of five time points during ages five through fourteen due to the two-year spacing of interview waves. In other words, the only selection decision I made is to limit the sample to children who have at least one valid math score, which cuts out the children who were too old (15+ years) when the study began in 1986 or were born late enough in the study (after 1997) that they never reached the assessment age of five by the last wave in 2002 (or were never assessed because they died before they reached age five). The pooling process led to a sample of 8497 individuals who have at least one valid math test score. 1266 children have 1 score, 1499 have 2 scores, 1464 have 3 scores, 2105 have 4 scores, and 2163 have all five scores. In the end, this process makes use of a total of 27,891 math score observations.

Variables

The PIAT-M measures a child's achievement in mathematics as it is commonly taught in American schools, and covers a wide range of materials from simple recognition of numerals to advanced concepts in geometry and trigonometry (Guo & Harris 2000). Math achievement test score gains are a useful measure of academic achievement for the following reasons. First, as mentioned earlier, the structure of

mathematical tracks in schools creates pathways through which children's academic achievement influences their future occupational and economic opportunities (Crosnoe, et al. 2004; Hallinan 2001; Stevenson, et al. 1994). Second, when examining how factors influence a child over time, measures of academic *achievement* should provide more informative results than measures of academic *ability*. This is because academic ability is a fairly stable trait that is mostly determined by genetic and early environmental factors, while academic achievement is more of an acquired trait that has a higher likelihood of being influenced throughout childhood and adolescence (Guo 1998; Draper 1974). Third, math achievement test scores may reveal more than reading achievement test scores about time-varying relationships during later childhood because researchers have found that oral language and reading skills are mostly determined at very early ages (Farkas & Beron 2004; Beron & Farkas 2004; Lonigan, et al. 2000), while math achievement might be more responsive to family influences at later ages.

This study uses poverty status as a time-varying measure of socioeconomic status because poverty is one primary aspect of socioeconomic status that previous research suggests explains relationships between family structure and academic achievement (Pong & Ju 2000; McLanahan & Sandefur 1994; McLanahan 1985). Also, poverty status is linked to other aspects of socioeconomic disadvantage, such as less cognitive stimulation, living in low-income neighborhoods, attending lower quality schools, and lower quality parenting (Amato 2005; Guo & Harris 2000).

Children's family structure at each time point will be defined as one of five possible categories: married biological parents, cohabiting biological parents, married stepfamilies (biological mother with stepfather), cohabiting stepfamilies (biological

mother with non-biological partner), and single-mother families. It is important to note that because the CNLSY sample is based on children of the female respondents of the NLSY-79, all of these family structures contain the biological mother. Thus, my sample does not include stepmother or single-father family structures.

In addition to the time-varying poverty and family structure effects on math achievement gains, the study will examine how children's gender and racial and ethnic identity (Hispanic, non-Hispanic Black, or non-Black/non-Hispanic) influence their math achievement over time. Also, because the CNLSY sample over represents children of younger and less educated mothers, I will control for such characteristics as the mother's age at the birth of the child, the mother's cognitive ability (as measured by her AFQT percentile score: a composite of verbal and math ability), and the mother's highest grade completed as of the first time point (when the child was age 5-6). These measures tend to capture certain aspects of the children's socioeconomic environment, and they are important to include in the analysis because previous studies using the CNLSY data have found that both mother's cognitive ability and educational attainment have significant positive effects on children's achievement test scores (Guo 1998; Garret, et al. 1994; Moore & Snyder 1991). Other control variables included in the analysis will be the child's birth cohort[1], the birth order of the child, the region of the United States (South, West, Northeast, or Northcentral) that the child lived in as of the first time point (age 5-6), and whether the child lived in an urban area (standard metropolitan statistical area: SMSA) as of the first time point (age 5-6).

Table 1 summarizes the statistics of where the children in this study stand on all these variables, while Table 2 summarizes the poverty and family structure statuses of the

[1] Birth Cohort: -3=1973-74, -2=1975-76, -1=1977-78, 0=1979-80, 1=1981-82, … , 8=1995-96, 9=1997-98

Table 1: Descriptive Statistics (N=8497)

Variable	Category	Frequency	Percent of Sample
Gender	Female	4167	49.0
	Male	4330	51.0
Race/Ethnicity	NH White	4123	48.5
	NH Black	2634	31.0
	Hispanic	1740	20.5
Urban Residence (SMSA) **	Urban	6346	74.7
	Not Urban	1904	22.4
	missing cases*	247	2.9
Region of Residence **	Northeast	1285	15.5
	North Central	2079	24.5
	South	3277	38.6
	West	1653	19.5
	missing cases*	203	2.4
	Range	**Mean**	**Standard Deviation**
Cohort	-3 to 9	3.4682	2.73568
Birth Order	1 to 10	1.9068	1.08231
Mother's Age at Birth of Child	13 to 39	24.2277	5.19548
Mother's AFQT Percentile Score *	1 to 99 missing N=355 (4.2%)	33.9413	26.75493
Mother's Highest Grade Completed * **	0 to 20 missing N=162 (1.9%)	12.1377	2.46691

* Missing values were imputed for use in analysis ** At Time 1: ~ age 5-6

children at each of the five possible time points. It is important to note that the lower numbers of available data among the older ages are not solely due to attrition. This pattern is also largely due to the fact that the children in more recent birth cohorts were not old enough to contribute to the later time points of the pooled data, which, in contrast

Table 2: Poverty and Family Structure Frequencies by Age (N=8497)

Age	Type*	Poverty**		MarBio**		CohBio**		MarStep**		CohStep**		SingMom**	
5-6 n=6495	Yes	1449	22.3	3844	59.2	229	3.5	327	5.0	214	3.3	1769	27.2
	No	4134	63.6	2521	38.8	6136	94.5	6038	93.0	6165	94.9	4376	67.4
	missing	912	14.0	130	2.0	130	2.0	130	2.0	116	1.8	350	5.4
7-8 n=6440	Yes	1456	22.6	3486	54.1	204	3.2	502	7.8	292	4.5	1831	28.4
	No	3999	62.1	2803	43.5	6085	94.5	5787	89.9	6017	93.4	4306	66.9
	missing	985	15.3	151	2.3	151	2.3	151	2.3	131	2.0	303	4.7
9-10 n=6044	Yes	1370	22.7	2975	49.2	139	2.3	653	10.8	315	5.2	1830	30.3
	No	3713	61.4	2913	48.2	5749	95.1	5235	86.6	5593	92.5	3952	65.4
	missing	961	15.9	156	2.6	156	2.6	156	2.6	136	2.3	262	4.3
11-12 n=5299	Yes	1153	21.8	2377	44.9	112	2.1	671	12.7	310	5.9	1695	32.0
	No	3221	60.8	2759	52.1	5024	94.8	4465	84.3	4852	91.6	3344	63.1
	missing	925	17.5	163	3.1	163	3.1	163	3.1	137	2.6	260	4.9
13-14 n=3613	Yes	787	21.8	1494	41.4	63	1.7	561	15.5	218	6.0	1179	61.7
	No	2218	61.4	2001	55.4	3432	95.0	2934	81.2	3297	91.3	2230	32.6
	missing	608	16.8	118	3.3	118	3.3	118	3.3	98	2.7	204	5.6

* Missing values were imputed for use in analysis ** 1st column has frequencies & 2nd has percentages

to attrition, is a product of the method used to arrange the data (pooling) rather than a defect in the data. Another important factor that may influence the robustness of my results is the low numbers of children in cohabiting families (especially in the later time points that are predominated by older cohorts that grew up during times when cohabitation was less common), which may create larger standard errors and a lower likelihood of finding significant effects of cohabiting family structures.

Method

This study uses growth curve modeling techniques which allow poverty status and family structure to vary over time. Missing values of the independent variables were imputed using the expectation-maximization (EM) method available in the missing value analysis options of SPSS. A special statistical software, HLM-6.0, is used to construct and analyze the growth curve models because it has the capacity to account for the correlations among an individual's repeated observations and also allows for the unbalanced data design that occurs from children having different numbers of valid math test scores (Raudenbush & Bryk 2002). The PIAT-M scores at each time point are the dependent variable while poverty status and family structure dummy variables serve as time-varying (level 1) covariates. The other variables (discussed above) appear in the time-invariant child characteristics level of the model (level 2) and are used to predict the intercept (starting point) and the age slope (rate of growth). Throughout the analyses, the age variables are coded in months and are centered on age five (60 months). The equation for the full linear growth model (without age interactions) is presented below for individual *i* at time *t*.

Level 1:

$$Math_{ti} = \beta_{0i} + \beta_{1i}(Age_{ti} - 60) + \beta_{2i}(Age_{ti} - 60)^2 + \beta_{3i}(Poverty) + \beta_{4i}(CohBio) + \beta_{5i}(MarStep) + \beta_{6i}(CohStep) + \beta_{7i}(SingMom) + e_{ti}$$

Level 2:

$$\beta_{0i} = \beta_{00} + \beta_{01}(Cohort) + \beta_{02}(Female) + \beta_{03}(Hispanic) + \beta_{04}(BlackNH) + \beta_{05}(BirthOrder) + \beta_{06}(MomAge@Birth) + \beta_{07}(MomAFQT) + \beta_{08}(MomHighestGradeCompleted) + \beta_{09}(Urban) + \beta_{010}(NCregion) + \beta_{011}(SouthRegion) + \beta_{012}(WestRegion) + r_{0i}$$

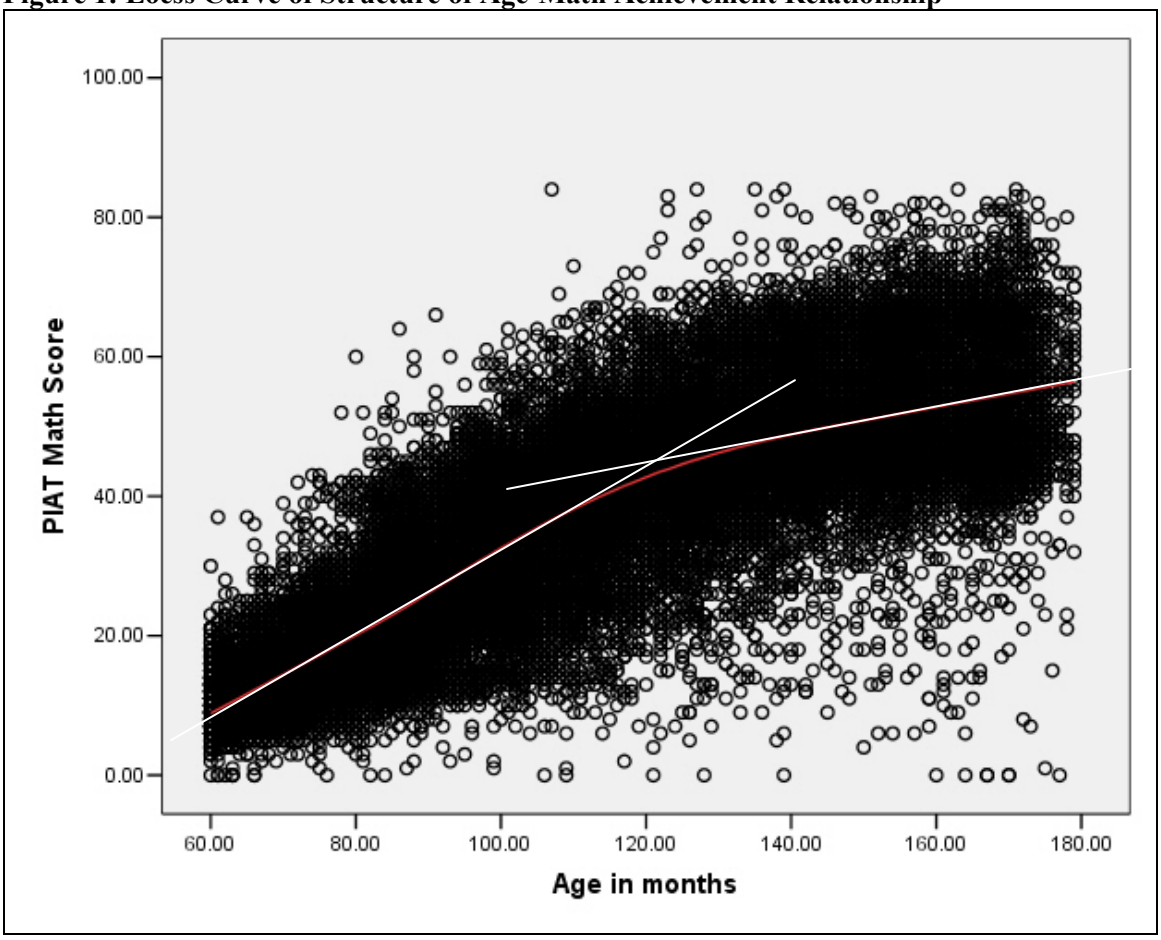
$$\beta_{1i} = \beta_{10} + \beta_{11}(Cohort) + \beta_{12}(Female) + \beta_{13}(Hispanic) + \beta_{14}(BlackNH) + \beta_{15}(BirthOrder) + \beta_{16}(MomAge@Birth) + \beta_{17}(MomAFQT) + \beta_{18}(MomHighestGradeCompleted) + \beta_{19}(Urban) + \beta_{110}(NCregion) + \beta_{111}(SouthRegion) + \beta_{112}(WestRegion) + r_{1i}$$

The decision about how to model the structure of the relationship between age and math achievement was an important one. I started by constructing some linear models (not shown), but soon found that adding an age-squared term provided for a much better model fit, due to the nonlinear nature of the age-math achievement relationship. However, all of the multiple interactions with the age and age-squared terms that were necessary to answer my final research question created some multicollinearity issues and were very complicated to interpret substantively. Therefore, I will not present the results of these nonlinear models. Instead, I will present the results of my final approach to model structure, which is a combination of two linear models that are run separately for children at younger and older ages.[2] In this approach, I broke the sample of observations into two parts by age and ran one regression for the 5-9 year olds (which includes 16049 observations from 7986 children who had at least one math score available within that age range) and another regression for the 10-14 year olds (which includes 11842 observations from 6313 children); thus, the majority of children in the full sample contribute age appropriate data to both regressions, while some children only have

[2] This final approach provides much better model fit statistics and produces coefficients that are easier to directly interpret while leading to substantive conclusions that are identical to the conclusions drawn from the full sample linear and nonlinear models.

observations available to contribute to one age-ranged regression.[3] This technique of running two separate linear regressions provides the best model fit because it most closely mimics the actual structure of the relationship between age and math achievement that is found in the CNLSY data (see Figure 1).[4]

Figure 1: Loess Curve of Structure of Age-Math Achievement Relationship



Results

My first research goal was to determine how the covariates of family structure and poverty status each relate to math test score gains, net of the other. Before adding the control variables, all four alternative family structure variables had significant negative

[3] This split limits my ability to assess within-person variance across the entire 5-14 age range, but this is not a large concern here because my focus is on assessing between-person differences at specific ages.
[4] I drew two straight lines over the loess curve to show how closely two separate linear regressions could approximate the actual structure of the age-math achievement relationship in the data.

effects on children's math score gains in both age groups, but after adding poverty status to the model, these effects were partially mediated by the significant negative effect of poverty status on math score gains (see Table 3). Yet, all the family structure variables

Table 3: Sequence of Models (Estimated by Restricted Maximum Likelihood)

Variable	1. Family Structure		2. Fam & Pov Status		3. Plus Controls		4. Plus Age*Pov	
	Age 5-9	Age 10-14	Age 5-9	Age 10-14	Age 5-9	Age 10-14	Age 5-9	Age 10-14
Intercept	9.400***	45.775***	9.664***	46.095***	3.600***	36.767***	3.229***	36.798***
Cohort					-0.221**	0.201	-0.222**	0.201
Female					0.555***	-0.332	0.553***	-0.332
Hispanic					-0.953***	-1.356**	-0.947***	-1.355**
NH Black					-0.706**	-2.328***	-0.752**	-2.322***
Birth Order					-0.327***	-0.674***	-0.351***	-0.673***
Mom's Age @ Birth					0.128**	0.092	0.133***	0.092
Mom's AFQT					0.033***	0.098***	0.034***	0.098***
Mom's Highest Grade					0.200***	0.327***	0.210***	0.326***
Urban					0.216	0.789*	0.233	0.787*
North Central Region					-0.272	-0.526	-0.263	-0.527
South Region					-0.239	-0.091	-0.227	-0.093
West Region					-0.343	-0.927	-0.335	-0.930
R0 (level 2 variance)	3.275	62.521***	2.775	59.813***	1.600	46.070***	1.608	46.032***
Age	0.600***	0.223***	0.599***	0.222***	0.552***	0.234***	0.570***	0.233***
Age*Cohort					0.011***	0.003	0.011***	0.003
Age*Female					-0.014*	-0.009	-0.014*	-0.009
Age*Hispanic					-0.003	0.009	-0.003	0.009
Age*NH Black					-0.038***	-0.017	-0.036***	-0.017
Age*Birth Order					-0.007*	-0.010*	-0.006	-0.010*
Age*Mom's Age @B					-0.003*	0.000	-0.003*	0.000
Age*Mom's AFQT					0.002***	0.001***	0.002***	0.001***
Age*Mom's High G.					0.004*	-0.002	0.004*	-0.001
Age*Urban					0.001	-0.013	0.001	-0.013
Age*North Central					-0.010	0.024	-0.011	0.024
Age*South Region					-0.003	-0.003	-0.004	-0.003
Age*West Region					-0.003	-0.010	-0.004	-0.010
R1 (level 2 variance)	0.022***	0.010***	0.022***	0.010***	0.018***	0.008***	0.018***	0.008***
Married Step	-1.246***	-2.130***	-1.089***	-1.936***	0.044	-0.042	0.021	-0.041
Cohabit. Biological	-2.052***	-5.366***	-1.216***	-4.439***	-0.014	-2.152**	-0.031	-2.150**
Cohabiting Step	-2.017***	-3.703***	-1.225***	-3.062***	-0.174	-0.832*	-0.187	-0.832*
Single Mother	-2.228***	-3.388***	-1.285***	-2.430***	-0.158	-0.223	-0.179	-0.222
Poverty Status			-2.112***	-2.508***	-0.564***	-0.515*	-0.143	-0.548
Age*Poverty Status							-0.019*	0.001
E (level 1 variance)	24.644	30.189	24.794	30.645	24.096	30.196	24.095	30.214
Deviance Statistic (4 parameters)	108320	85082	108140	84959	106073	83258	106061	83255
R-squared	0.018	0.029	0.030	0.053	0.096	0.201	0.096	0.202
N children	7986	6313	7986	6313	7986	6313	7986	6313
N observations	16049	11842	16049	11842	16049	11842	16049	11842

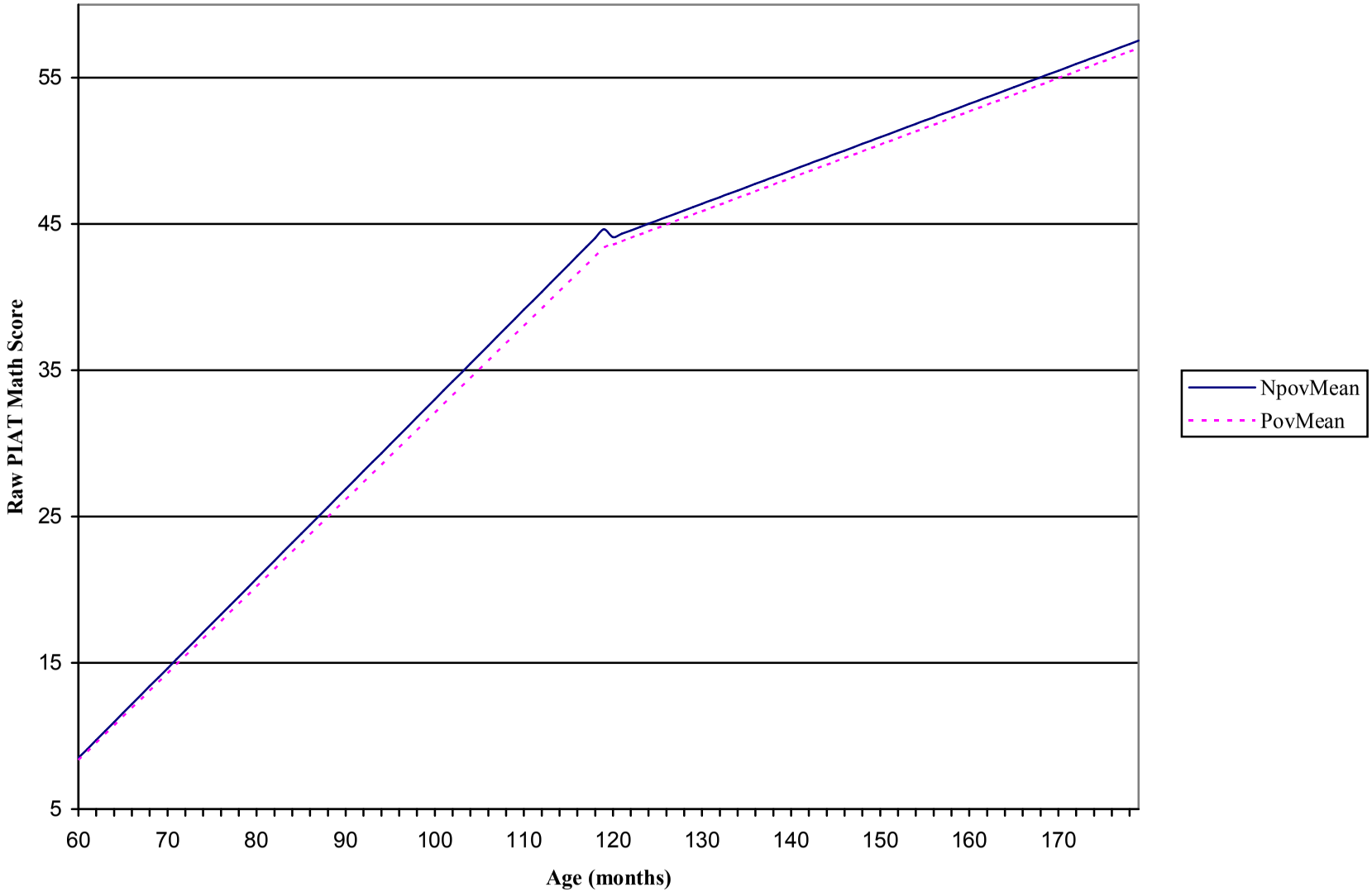
*p<0.05 **p<0.01 ***p<0.001

maintained a significant negative effect when controlling for poverty status. Adding the control variables to the model reduced all the family structure effects to non-significance in the 5-9 age group and reduced all the family structure effects in the 10-14 age group while only fully explaining the effects of single mother and married stepfamily structures; the effects of both types of cohabiting families, while reduced in magnitude, remained significant for the 10-14 age group, net of poverty status and all the control variables. The addition of controls greatly decreased the negative effect of poverty status but did not completely explain it because poverty status remained significant for both age groups.

Next, I interacted age with poverty status and with family structure to see if the effects of my main variables of interest change according to age within each of my age groups. In other words, I tried to assess whether the gaps between children in different family structures or poverty statuses grew or shrunk throughout early childhood or later childhood. The interactions between age and family structure were not significant (not shown), so I will not discuss them further. However, the interaction between age and poverty status was significant for the 5-9 age group, which reduced the main effect of poverty status to non-significance, and not significant for the 10-14 age group. Thus, for my final model that is represented in all my graphs, I chose to use the 3rd model for the 5-9 age group (because the 4th model did not add explanatory power for the younger children) and the 4th model for the 10-14 age group (because the age*poverty term had significant explanatory power for the older children).

Figure 2 is a graph of the predicted growth curves of math achievement scores among children above and below the poverty line. The negative coefficient for the interaction between age and poverty status in the ages 5-9 regression indicates that the

Figure 2: Poverty Status and Math Achievement



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negative effect of being in poverty on math achievement (that starts out as non-significant) increases in magnitude during early childhood. This increase in the strength of the negative poverty effect throughout early childhood results in significantly lower math scores among children in poverty by age 10, as evidenced by the significant negative poverty status coefficient in the ages 10-14 regression. However, this negative poverty effect seems to stabilize by about age 10 because the age*poverty interaction was not significant for the 10-14 age group.

Figure 3 is a graph of the predicted growth curves of math achievement scores for children in the five family structures in this study. During early childhood, there are no significant differences between the married biological family structure and the four alternative family structures that are not explained by poverty status and all the controls variables. However, during later childhood there are significant negative effects for both of the cohabiting family structures, net of poverty status and controls. Interestingly, the negative effect of living with cohabiting biological parents is much stronger than the negative effect of living in a cohabiting stepfamily. As mentioned earlier, there are no significant interactions between age and the alternative family structure in either of the age groups. Therefore, the gaps between children in married biological and cohabiting family structures remain stable throughout later childhood.

Another goal of this study was to assess how gender, race/ethnicity, and certain characteristics of the mother influence children's math score gains, and how these relationships change throughout childhood. This was accomplished by including these variables as predictors of the structural variables of the model (the intercept and age slope). This allowed me to observe both how these variables impact where children start

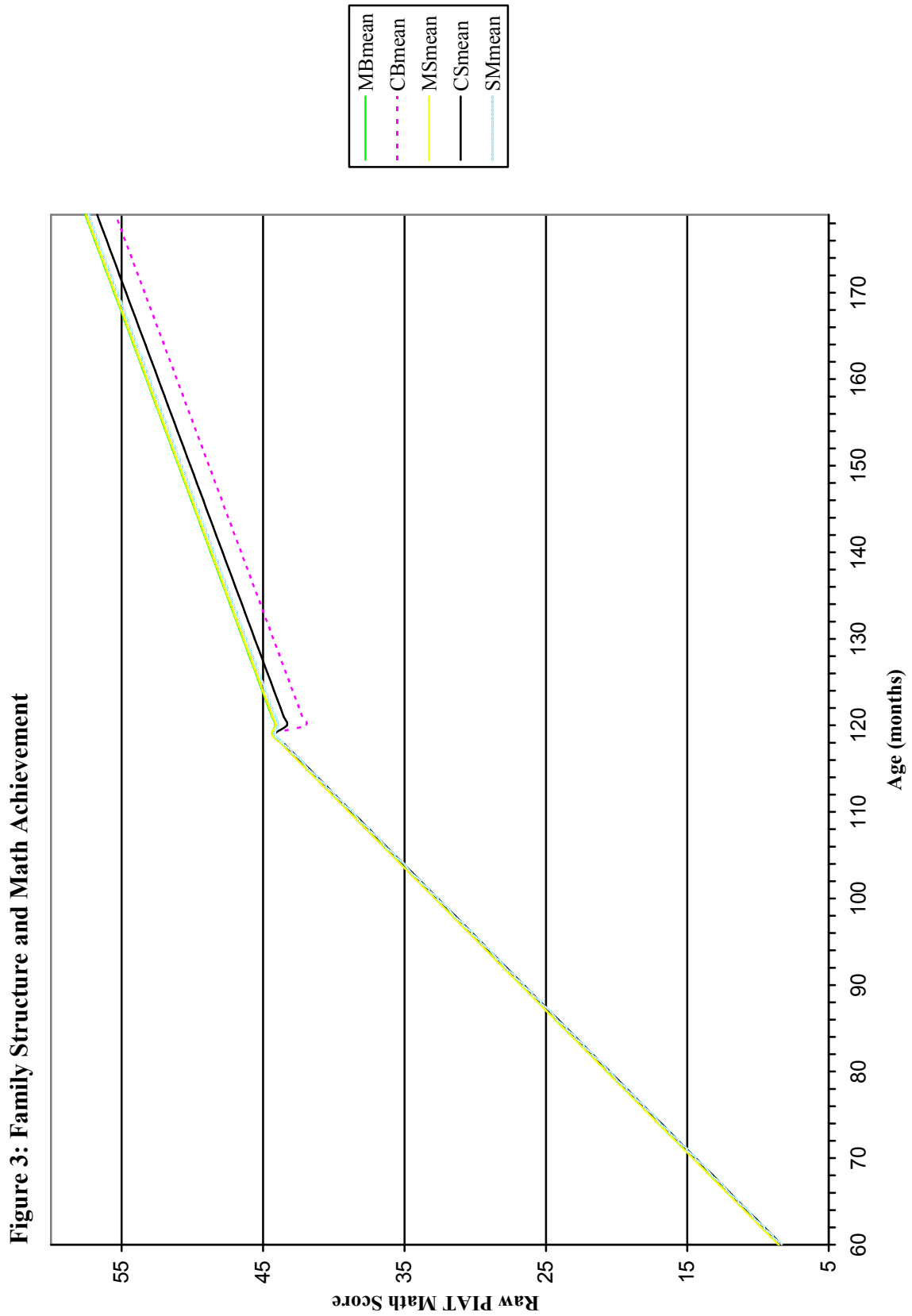

Figure 3: Family Structure and Math Achievement

at age five and ten and how the effect of these variables changes over time within each age group.

For gender effects I found that females start with significantly higher math achievement scores at age five, but they grow at a significantly slower rate than males. This pattern causes females to then end up scoring lower than males on math achievement by middle childhood (about age 9-10) and remain below males after that point (see Figure 4 in Appendix). However, the magnitude of the resulting male advantage in later childhood is modest. In regards to race/ethnicity, I found that both Hispanics and non-Hispanic blacks start at age five with significantly lower math achievement scores than non-Hispanic whites. However, non-Hispanic blacks grow at significantly slower rates than non-Hispanic whites, while Hispanics do not (see Figure 5 in Appendix). This causes the math achievement gap between whites and blacks to widen over time while the gap between whites and Hispanics remains the same size. This pattern continues during later childhood, except that the interaction between age and being a non-Hispanic black is not large enough to be significant during these later ages.

Three characteristics of the mother were of interest for my analyses because they have been found to influence achievement test scores in past research using the CNLSY data: mother's age at the child's birth, mother's cognitive ability (AFQT score), and mother's educational attainment (highest grade completed). I found that children of older mothers score significantly higher on math achievement than children of younger mothers. I also found that children of older mothers gain at a significantly slower rate than children of younger mothers during early childhood, but then tend to grow at the same rate as children of younger mothers during later childhood, with children of older

mothers still ending up ahead of children of younger mothers (see Figure 6 in Appendix). However, this effect of mother's age at birth is no longer significant for the 10-14 age group. The effect of mother's cognitive ability was a strong predictor of children's math score gains. Children of mother's with higher AFQT scores start with significantly higher math achievement scores at age five, and they also grow at significantly faster rates for both age groups, widening the gap over time (see Figure 7 in Appendix). Children of mothers with higher educational attainment start with significantly higher math achievement scores at age five, and they do grow at a significantly faster rate than children of mothers with lower educational attainment during early childhood, while the math achievement gap stayed the same size over time during later childhood. However, the effect sizes of mother's highest grade completed, while significant, appear to be somewhat modest when observing the predicted growth curves (see Figure 8 in Appendix).

In addition to interactions with age, I also tested for interactions between poverty status and the alternative family structures (not shown). Some of these interactions were significant, but the patterns were not clear. Therefore, I ran the age split models separately for children in poverty and for children not in poverty, and I found there are no significant family structure effects among children who live in poverty, net of controls (see Table 4). Yet, the negative effect of cohabiting family structures that remained significant in the whole sample of older children shows up stronger among the sample of older children that are not in poverty. This result affirms that there is something about cohabiting family structures that reduces children's math achievement that cannot be explained by poverty status or any of the control variables in my model.

Table 4: Separate Models by Poverty Status (Estimated by Restricted Maximum Likelihood)

Variable	Family Structure & Controls			
	5-9 Pov	10-14 Pov	5-9 NonPov	10-14 NonPov
Intercept	3.082	29.810***	2.506*	38.572***
Cohort	-0.076	-0.014	-0.288**	0.223
Female	0.597*	0.833	0.565**	-0.731*
Hispanic	-1.259**	0.701	-0.760**	-1.858***
NH Black	-0.533	-1.733*	-0.630*	-2.448***
Birth Order	-0.543***	-0.926**	-0.334**	-0.516*
Mom's Age at Birth	0.175*	0.234	0.163**	0.044
Mom's AFQT	0.019*	0.130***	0.035***	0.095***
Mom's Highest Grade Comp.	0.126	0.435*	0.227***	0.319**
Urban	0.248	0.322	0.178	0.834*
North Central Region	-0.166	2.062	-0.122	-1.356*
South Region	-0.144	1.138	-0.303	-0.436
West Region	0.044	-1.575	-0.457	-1.022
R0 (random effect)	0.197	46.804***	2.710	43.246***
Age	0.495***	0.404**	0.601***	0.173**
Age*Cohort	0.004	0.006	0.013***	0.004
Age*Female	-0.001	-0.021	-0.019**	-0.005
Age*Hispanic	0.023	-0.013	-0.015	0.011
Age*NH Black	-0.031	-0.023	-0.041***	-0.004
Age*Birth Order	-0.004	-0.002	-0.004	-0.016*
Age*Mom's Age at Birth	-0.002	-0.003	-0.004*	0.003
Age*Mom's AFQT	0.003***	0.001	0.002***	0.001**
Age*Mom's Highest Grade C.	0.002	-0.007	0.004	-0.002
Age*Urban	0.010	-0.019	-0.002	-0.006
Age*North Central Region	0.020	-0.043	-0.027*	0.045**
Age*South Region	0.018	-0.044	-0.007	0.012
Age*West Region	0.001	-0.021	-0.002	0.003
Age*R1 (random effect)	0.028***	0.008**	0.015***	0.011***
MarStep	-0.781	0.842	0.209	-0.187
CohBio	0.203	-1.049	-0.279	-2.661**
CohStep	0.627	0.107	-0.648	-1.175*
SingMom	0.009	0.467	-0.293	-0.502
E (level 1 variance)	21.369	32.610	24.353	28.656
Deviance Statistic (4 par.)	24212	18628	69314	53300
R-squared	0.039	0.106	0.087	0.180
N children	2592	1916	5920	4655
N observations	3627	2596	10423	7539

*p<0.05 **p<0.01 ***p<0.001

Discussion

The time patterns of the effects of poverty and family structure on math achievement gains that were found in this analysis are interesting when compared to the seemingly conflictual findings of Guo (1998) and Duncan, et al. (1998) about the timing

of poverty effects on children's academic achievement. My analysis showed that, net of family structure and control variables, the negative effects of poverty status on math achievement scores grow significantly throughout early childhood (ages 5-9), but have a small stable effect throughout later childhood and early adolescence (10-14). At first, one might be tempted to compare this pattern with the seemingly contradictory findings of Guo (1998) and Duncan, et al. (1998). However, the method used in my analysis answers a different type of question than these two previous studies. These two previous studies assess how economic conditions experienced during early childhood influence academic achievement measured during later childhood or early adolescence, while my current method of using time-varying covariates in a growth curve model examines how poverty (or family structure) experienced at a certain age influences math achievement at that specific age and how the relationship between these variables differs by age. Therefore, the findings of my analysis can add another dimension to these previous findings, rather than confirming or contradicting them.

While my research indicates that poverty exerts more influence on achievement during early childhood, I also found that the effects of alternative family structures are minimal during early childhood, while children in cohabiting family structures fare significantly lower on math achievement than children living with married biological parents during later childhood. This phenomenon appears at about age 10, with the negative effect being much stronger for children living with cohabiting biological parents than for children living in a cohabiting stepfamily, and these effect sizes remain stable throughout later childhood and early adolescence.

In considering why children living with cohabiting biological parents would fare worse than children living in cohabiting stepfamilies, it would be useful to consider that if two cohabiting biological parents are still together when their child is age 10-14, they might have stayed together out of obligation to the child after the mother got pregnant, rather than out of commitment to the romantic relationship. But when a mother is cohabiting with a partner that is not the child's father, the relationship could be more recently formed and would have been formed on the basis of choosing to be together while knowing that a child would be part of the equation. Not having a child allows more flexibility for a cohabiting union to be dissolved if the relationship is not as good as one would hope. Now, if the similarities between a cohabiting union and a marriage are taken into consideration,[5] there is evidence that staying in a low-quality relationship is associated with lower levels of overall happiness, life satisfaction, self-esteem and health and higher levels of psychological distress, compared to people who end their unhealthy relationships and move on (Hawkins and Booth 2005).[6] Children who live with these cohabiting biological parents that may be staying together for the child, despite major relationship issues, could be experiencing negative academic outcomes because the unhappiness of their parents is affecting the child's general well-being through parental conflict and lower emotional parental resources. Studies have found that children that must remain in high-conflict households are just as negatively affected as, or sometimes worse off than, children who experience a divorce (Booth and Amato 2001; Jekielek 1998).

[5] Brown and Booth found that the relationship quality of married couples and cohabiting couples who report that they plan to marry (which is the majority of cohabiters) is affected in similar ways by the presence of children and prior union experience (1996).

[6] Hawkins and Booth find this pattern to be true of married couples that stay together despite a low-quality relationship, rather than getting a divorce and possibly remarrying (2005).

Several different theoretical arguments could be useful to consider in the context of my current findings about the different time patterns of family structure and poverty status effects on achievement. The critical period hypothesis claims that there is a critical period in a child's life when he or she needs to be exposed to certain productive learning experiences in order to avoid lasting damage to his or her cognitive ability (Guo 1998). The finding that the negative effects of poverty on math achievement grow throughout early childhood and then remain stable and modest in later childhood and early adolescence could be partially explained by this critical period theory. This is because ability tests measure a person's potential rate of learning while achievement tests measure what is actually learned (Guo 1998). Thus, achievement is largely dependent on ability and could react to poverty in a similar way during early childhood.

My finding that negative cohabiting family structure effects have a larger impact during later childhood and early adolescence could be explained by a theory of motivation and opportunity. Research finds that whether people reach their potential achievement level or not (based on maximization of ability) is greatly influenced by their perceived opportunities and their motivation to achieve (Guo 1998; Henderson & Dweck 1990). Some researchers argue that minority adolescents have lower achievement due to a lack of motivation that is produced through the observation of an unfair opportunity structure (Guo 1998; Mickelson 1990; Ogbu 1986). As children grow old enough to understand how their current academic endeavors relate to their future educational and occupational opportunities, they can develop more or less motivation to push for high achievement based on their perception of how well those efforts might be rewarded. Thus, children who feel disadvantaged by their family structure might be less motivated

to achieve. This theory of motivation and opportunity could also be used to explain the findings about the effects of gender and race on math achievement gains. According to this theory, females and non-Hispanic blacks should be less motivated to give effort to their mathematical classes if they see their opportunities in the future as being limited to careers that are not rewarded by high math achievement.

Another possible explanation for these interesting time patterns of poverty and family structure effects could be framed around the findings of my split age model and the current structure of the educational system. Because the age split is based around the transition from elementary school to middle school, the structure and sequencing of mathematical education in American schools can give insight into these patterns. When children are first starting elementary school, the variance in math test scores is not as large because the children have been exposed to similar levels (small amounts) of formal mathematical lessons. However, as children progress through elementary school, the necessary math skills become more complex and homework assignments are introduced, creating a larger need for parental involvement and resources. Research has found that most of the negative effect of poverty on children's intellectual development can be explained by a lack of cognitive stimulation within the home (Guo & Harris 2000). Therefore, the negative effect of poverty grows throughout elementary school and creates achievement gaps that will help decide which tracks children will be placed into when they enter middle school. Because I found that mother's cognitive ability and educational attainment account for part of the poverty effects found in my model without controls, it is likely that a lack of cognitive stimulation in the home might also partially explain the effects of these characteristics of the mother on children's math achievement gains. For

example, a previous study found that the degree of intellectual stimulation in the home reduced to non-significance the effect of mother's cognitive score on Hispanic children's vocabulary test scores (Moore and Snyder 1991).

Upon entrance into middle school, the tracking system creates different paths to higher and lower math achievement that cause inequalities between children of different family structures to grow. This could happen because a child who persistently remains in a disadvantaged family structure starts in a lower track and continues on in less advanced math courses throughout middle school, essentially forcing the disadvantage to remain. This explanation is also known as Jensen's cumulative deficit hypothesis (Guo 1998). The idea that achievement deficits are cumulative because subsequent learning depends on previous learning is especially true within the tracking systems of math classes. Another possible reason for the observed growth of family structure inequalities upon entrance to middle school could be a product of a process in which older children and young adolescents are sensitive to changes in family structure that could knock them down from a higher track to a lower track because emotional stress has decreased their motivation for academic effort.

Conclusion

The findings of this study have some important implications that should be considered. First, the fact that a mother's cognitive ability and her educational attainment both have significant positive effects on a child's math achievement means that policy makers should consider ways to supplement the intellectual and educational contributions that less educated mothers make in their children's lives in order to increase the math achievement potential of these children. Second, the negative poverty effects that grow

during early childhood should indicate that efforts to supplement parents' economic resources should be focused on parents of elementary aged children. There should also be more emphasis placed on improving cognitive stimulation within the homes of children with parents that have low socioeconomic status. Finally, there should be programs for middle school children that help motivate females, blacks, and children experiencing family instability to reach their math achievement potential by opening their eyes to the future opportunities they could be rewarded with if they succeed in their math classes.

This study has several strengths. First, the data is from the children of a nationally representative sample of women. Second, the sample size is large. Third, the design of the CNLSY allows me to make use of as many as five time points from each individual child. Also, the hierarchal modeling strategy allows me to account for the correlations among each individual's repeated observations and gives me the ability to take advantage of an unbalanced data design, in which each child can have a different number of available observations. Finally, the use of the time-varying covariates of poverty status and family structure can answer the question of how these factors influence math achievement in a different way than models that only use an average of these variables over time.

This study also has some weaknesses. For example, the low numbers of cohabiting families among the older children make it difficult to detect significant effects of these important family types.[7] Another weakness of this study is that I could not include a measure of family instability (number of transitions) to see if it could explain

[7] However, this weakness highlights the strength of the negative effects of cohabiting family structures, because these coefficients achieved significance despite their higher standard errors.

the remaining effects of cohabiting family structures during later childhood that were not explained by poverty status and the control variables. Because of the unbalanced data structure (differing numbers of available time points for each child), the amount of missing data in a cumulative variable that sums transition experiences across time was too much would either cause me to drop a large portion of my cases or would create instability in the imputation process.[8] Therefore, I can only speculate that the remaining effects of living in a cohabiting family structure during later childhood might be due to an unstable family environment.

In the future, researchers need to continue to examine the relationships between family structure, economic resources, and children's academic outcomes. More specifically, they should attempt to make the age patterns of the effects more clear. Also, more data is needed on cohabiting families in order to be able to more accurately assess the effects of these newer family structures on children's academic outcomes and overall well-being. There should also be more research that investigates how the factors of family structure, particularly cohabiting family structures, and the economic resources of a child's parents impact academic achievement during high school and college. However, this current study is valuable to the discipline of sociology because it reaffirms previous findings about the effects of mothers' socioeconomic characteristics on children's academic achievement and sheds new light on the question of the timing of poverty effects on children's achievement. This study also starts to address the question of when family structure has the strongest impact on children's academic achievement

[8] I am currently attempting new ways of constructing this variable to see if I can use multiple imputation and include this variable in future analyses.

net of socioeconomic factors, which, to the best of my knowledge, is a question that has not been addressed in the literature before now.

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Appendix

Figures 4-8

Figure 4: Gender and Math Achievement

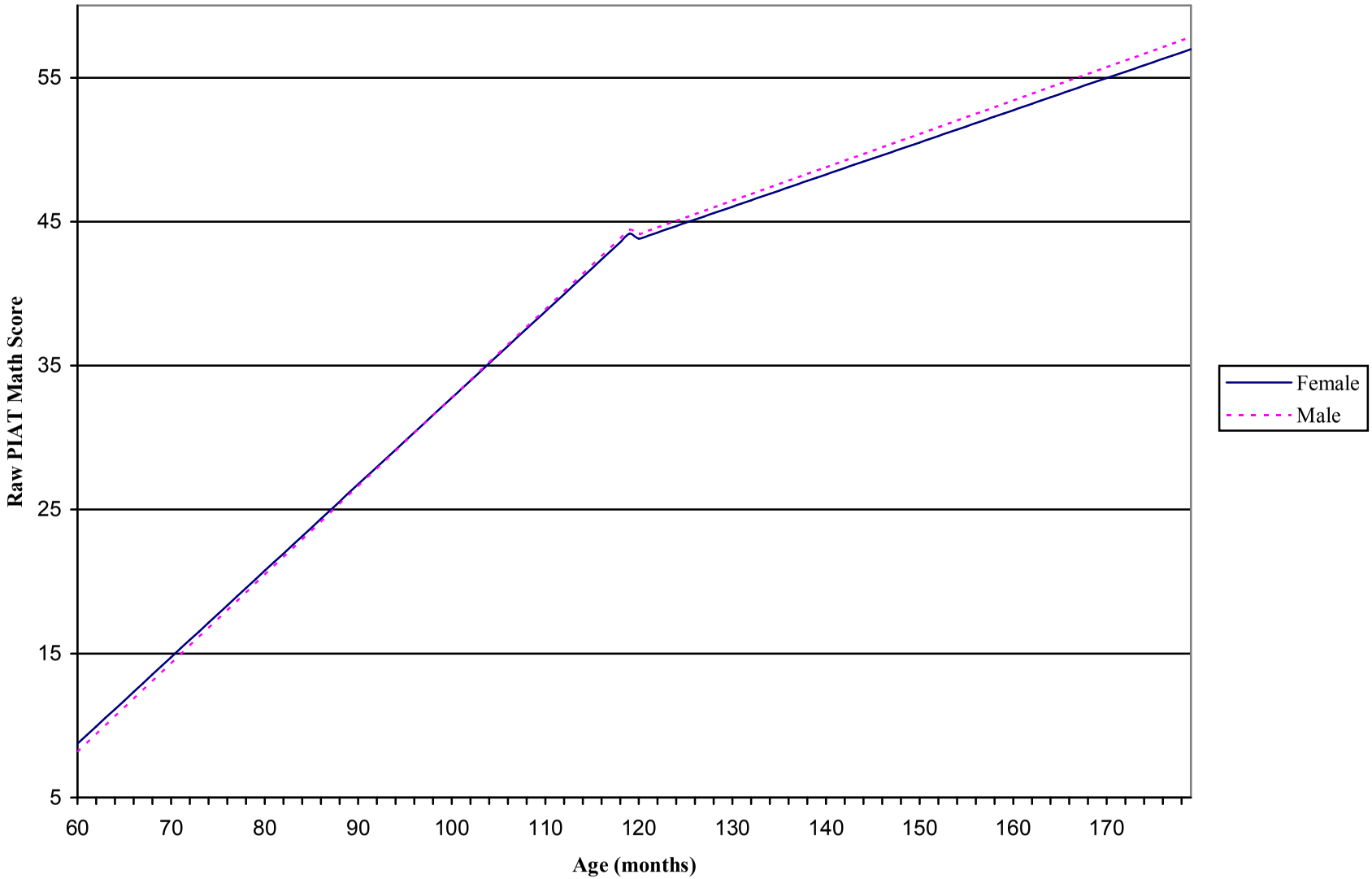

Figure 5: Race/Ethnicity and Math Achievement

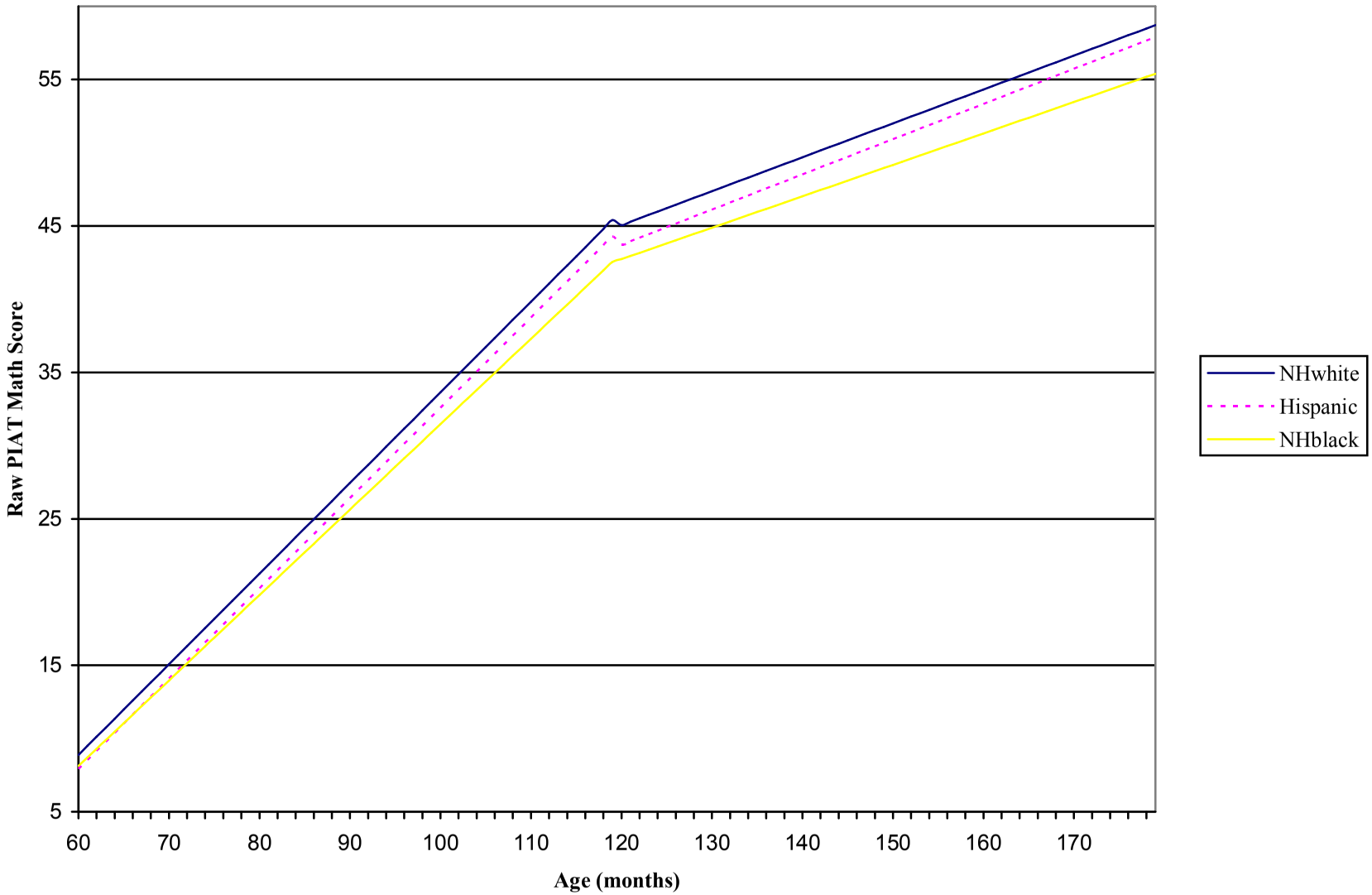

Figure 6: Mother's Age at Birth of Child and Math Achievement

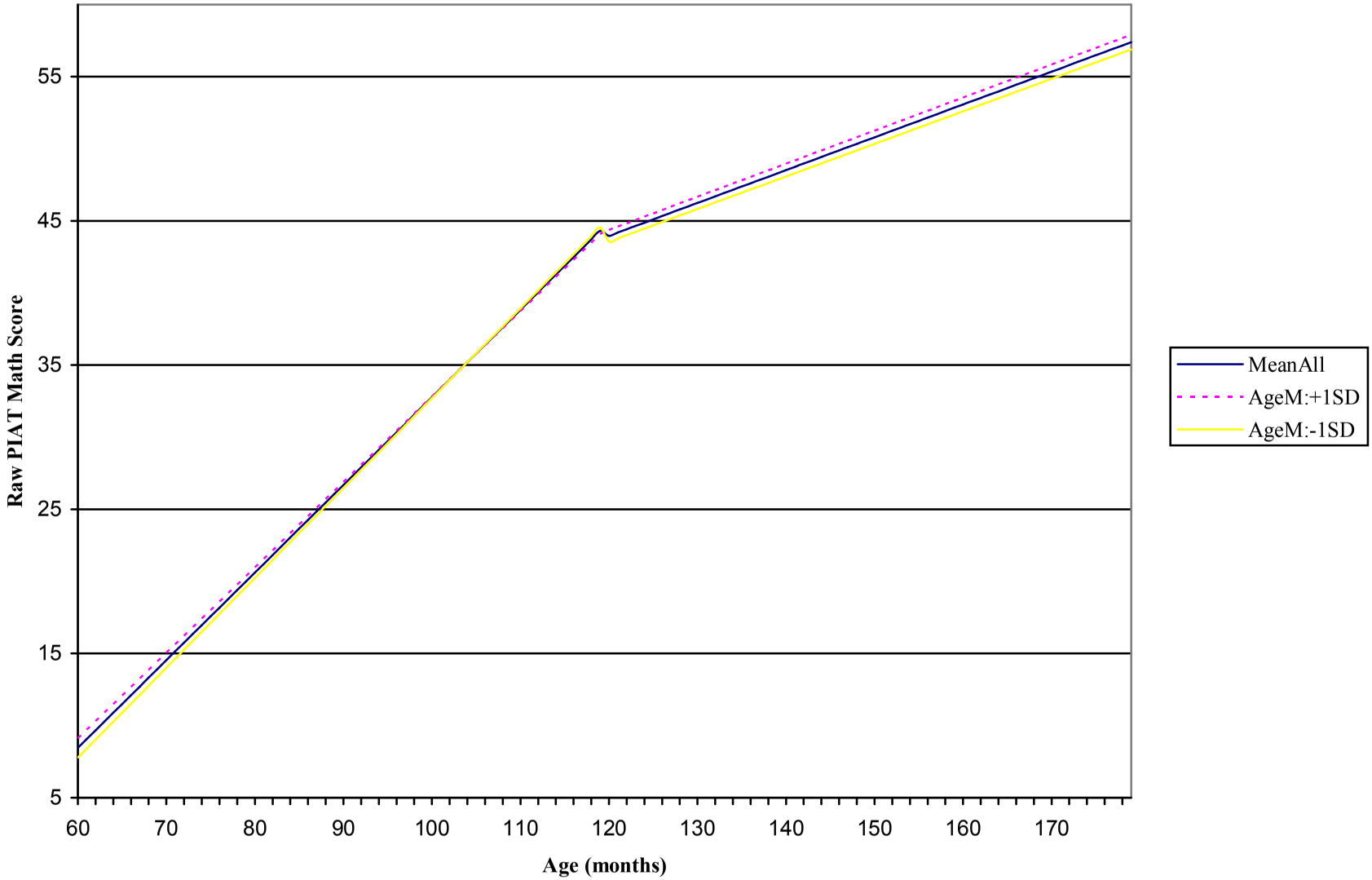

Figure 7: Mother's Cognitive (AFQT) Score and Math Achievement

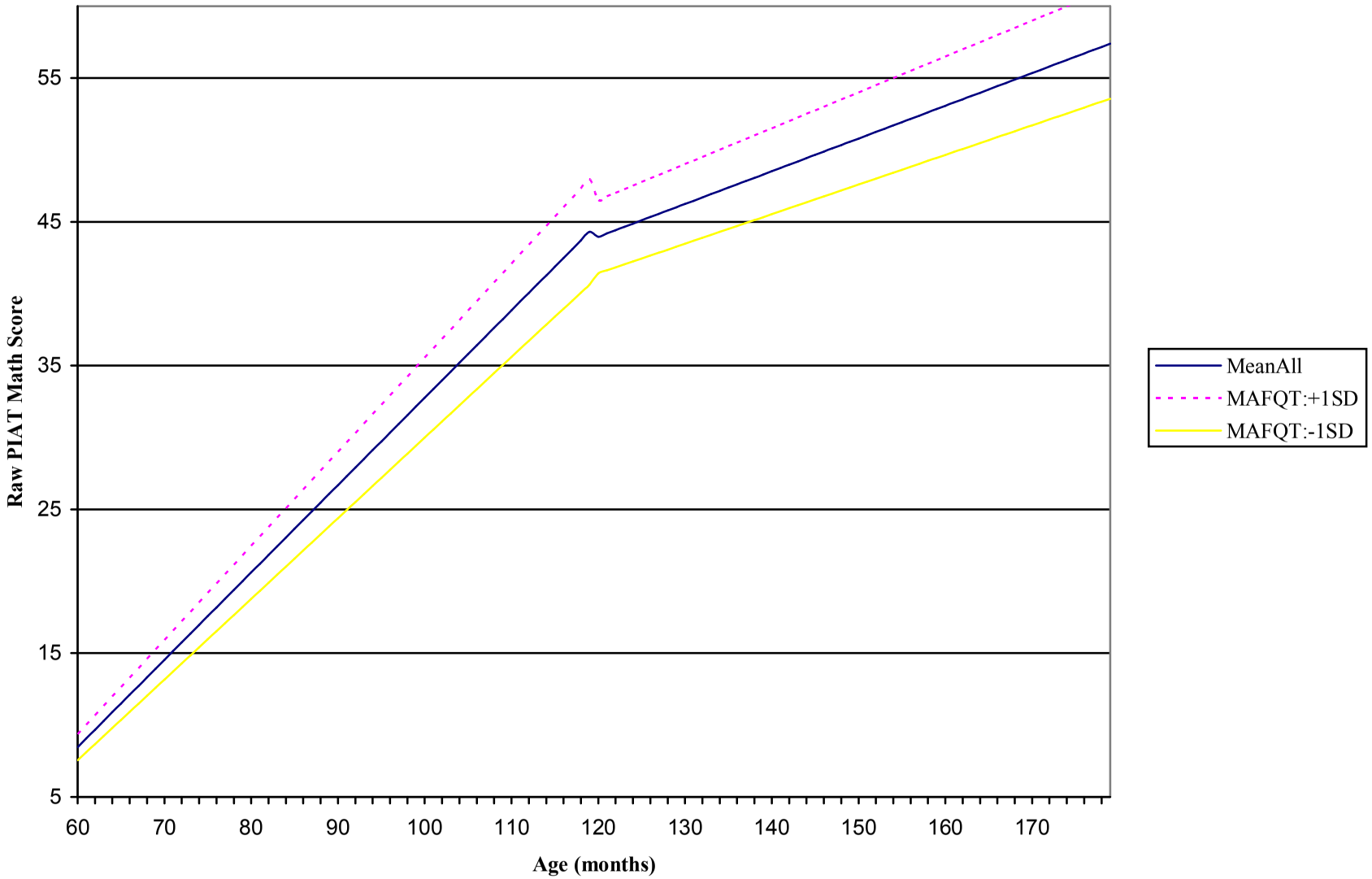

Figure 8: Mother's Highest Grade Completed and Math Achievement