Associations between birth weight/gestational age and social/cognitive functioning across development: Do differences endure?

A DISSERTATION SUBMITTED TO THE FACULTY OF THE UNIVERSITY OF MINNESOTA BY

William F. Johnson

IN PARTIAL FULFILLMENT OF THE REQUIERMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Jeffry A. Simpson, Mark Snyder

August 2018

Copyright Page

Acknowledgements

Thank you to my advisors and committee for their guidance and encouragement throughout my graduate career and the dissertation process. Especially, I would like to thank R. Chris Fraley for providing his expertise to a student he had never met at an institution where he does not teach. Thank you to Jason Weaver, for allowing me into his lab at Macalester seven years ago and giving me the opportunity to find my way in the world of research.

Thank you to my friends and colleagues in the social program and ICD for talking through ideas and analyses. Thank you to *all* my friends for support and good cheer as I wrote. Thank you to my parents, Patrice and Douglas, for supporting, encouraging and loving me throughout my life. Most of all, thank you to my wife, Madelyn, for everything.

Table of Contents

List of Tables

List of Figures

Abstract

This study uses data from the Minnesota Longitudinal Study of Risk and Adaptation (*N = 267)* to test whether birth weight and gestational age prospectively predict cognitive functioning and social competence throughout childhood, adolescence and early adulthood. Using multiple developmentally appropriate indicators of cognitive and social functioning, structural model comparisons test whether Enduring Effects or Revisionist Effects models of development better explain the associations between birth weight/gestational age and cognitive/social functioning. Of the four comparisons (birth weight predicting cognitive functioning, gestational age predicting cognitive functioning, birth weight predicting social competence, gestational age predicting social competence), only birth weight and cognitive functioning were consistently associated across development. The Revisionist Effects model best explained these relations, such that direct associations did not persist over time. Instead, birth weight had direct associations with cognitive functioning in early childhood that were carried forward through stability in cognitive outcomes through early adulthood. These findings are discussed in context of other tests of the Enduring Effects vs. Revisionist Effects models, developmental theory, and intervention application.

Associations between birth weight/gestational age and social/cognitive functioning across development: Do differences endure?

Birth weight and gestational age are among the earliest available indicators of post-natal health.. Birth weight is a useful indicator of pre-natal environment, is predicted by important social and structural factors, and in turn predicts salient later life outcomes (Bhutta, Cleves, Casey, Cradock & Anand, 2002; Hack, Klein & Taylor, 1995). Birth weight and gestational age, therefore, can offer researchers and practitioners a first view into a person's development. In addition, the potential for enduring associations between birth weight and cognitive/social functioning is of import for social and developmental psychologists, both in terms of understanding the developmental trajectories of essential competencies and for potentially identifying at the earliest possible time point children might benefit from intervention.

Cognitive ability and social competence are critical markers of competent adult living, with cognitive functioning powerfully predicting educational attainment, job performance, and socioeconomic status (Neissar et al., 1996). Social competence in middle childhood in turn predicts important adult competencies, such as romantic effectiveness (Simpson, Collins, Tran & Haydon, 2007), supportive parenting (Raby et al., 2015), workplace success (Collins & Van Dulmen, 2006), and substance use (Englund, Egeland, Oliva & Collins, 2008). This dissertation examines the predictive power of birth weight and gestational age across development and provides new information by examining differences in social functioning within the normative range of birth weight/gestational age, and it tests competing models of enduring vs. diminishing associations across development.

Determining if the associations between birth weight/gestational age and social/cognitive functioning diminish or endure over time can provide important (and novel) information to practitioners and theorists. One effective and useful way of comparing the long-term potency of these associations is by comparing whether the available data better fit the Revisionist Effects or Enduring Effects framework (Roisman & Fraley, 2013). The *revisionist* model of development states that early experiences proximately impact behavior but, as a child grows older, new experiences eventually overwrite associations between the earliest events and later outcomes. The *enduring effects* model of development assumes that early factors affect proximal (early) behavior *and* continue to directly impact later cognition and behavior, above and beyond contemporaneous variables. These two models have been effectively compared in other areas of development (Haltigan, Roisman & Fraley, 201; Raby, Roisman, Fraley & Simpson, 2015; Raby, Roisman, Labella, Martin and Fraley), but not using birth weight or gestational age.

Birth weight and gestational age are by no means understudied topics. There is ample evidence that being born early and/or at low weight may have detrimental consequences for cognitive and social functioning. However, the majority of research has examined differences in birth weight and gestational age among the small segment of the population meeting clinical thresholds for prematurity and low birth weight. In a study of over 6 million singleton live births in the years 1999-2000, less than 10% of infants born with a gestational age of 36 and 37 weeks were born weighing less than 2500 grams, which is the bottom cutoff for the normal range of birth weight (Oken, Kleinman, Rich-Edwards & Gillman, 2003). This dissertation will focus on the effects of children born within the normative range, rather than analyzing them homogenously as “normal birth weight” in contrast to infants born below the normal range.

Additionally, measurement of social outcomes has focused on the clinical rather than normative range. Many studies reporting the downstream social correlates of birth weight and gestational age examine the differences in prevalence of psychopathology, as opposed to social competence variation within the sub-clinical spectrum. By focusing on non-clinical predictors and outcomes, this dissertation attempts to measure and serve a wider range of infants than previous investigations.

Finally, this dissertation will formally test for the first time whether the links from birth weight and gestational age to cognitive and social functioning endure or desist over the early lifespan. The effect of birth weight is often studied cross-sectionally, although several studies have used a longitudinal design (e.g. Boardman, Powers, Padilla & Hummer, 2002; Richards, Hardy, Kuh & Wadsworth, 2001; Strauss, 2000). Even studies using longitudinal designs typically do not account for indirect associations through intervening outcomes when assessing long-term associations between natal variables and later functioning. The examination of enduring vs. diminishing effects is not simply a methodological distinction from previous work: it reveals the potential scope of variation in birth weight and gestational age. There is extensive research on associations between birth weight and a variety of downstream outcomes, but the nature of these associations (especially in the range inhabited the vast majority of infant birth weight/gestational age) remains unexamined. By harnessing the power of repeated, standardized measurement, this dissertation will test explicitly the persistence of birth weight and gestational age over childhood, adolescence and young adulthood, providing a clearer picture the potential risk of being born light and early within the normative range.

These longitudinal data also allow for the first examination of the dynamic nature of the association between birth weight/gestational age and cognitive/social functioning across the early lifespan. This dissertation will test whether associations between birth weight and these later life factors attenuate to zero as they are overwritten by more important proximal factors over time (the *revisionist* model) or whether birth weight/gestational age directly impacts cognitive and social functioning into early adulthood (the *enduring effects* model).

In this introduction, I first discuss the definitions, predictors and long-term health impacts of birth weight and gestational age. Then, I will review the extant literature on associations between birth weight/gestational age and cognitive functioning and social functioning. I note, in particular, studies using a longitudinal design and those that examined variation within the normal range of both the predictor and outcome variables.

Defining Birth Weight and Gestational Age

Research on the long-term associations between birth weight and cognitive/social functioning is often conducted by comparing children born in the normal range of birth weight (NBW, 2500 grams through 4000 grams/5.5 pounds through 8.8 pounds) to children born below this weight range. The literature on birth weight also categorically classifies infants born far below the normative range. Children born between 1500 grams through 2499 grams / 3.3 lbs. through 5.5 lbs. are classified as low birth weight (LBW); children born between 1000 grams through 1499 grams / 2.2 lbs. through 3.3 lbs. are classified as very low birth weight (VLBW); and children born at less than 1000 grams /

2.2 lbs. are classified as extremely low birth weight (ELBW). Conversely, children born above 4000 grams / 8.8 lbs. are considered high birth weight (HBW).

Much like birth weight, gestational age is most often examined categorically, examining normal age as compared to children born preterm. Children born between 38 through 42 weeks are classified as normal gestational age (NGA), children born between 35 through 37 weeks are classified as early gestational age (EGA), children born between 32 through 34 weeks are classified as very early gestational age (VEGA) and children born before 32 weeks are classified as extremely early gestational age (EEGA). Although there are some methods for aggregating gestational age and birth weight (Oken et al., 2003), I will examine them separately to test their unique associations with later functioning.

Predicting Birth Weight and Gestational Age

Although this examination uses birth weight as a predictor of social outcomes, birth weight itself is the product of parental genetics and mother's social environment. Genes are the foremost influence on a child's birth weight. Simple parental height and weight are the most predictive variables of an infant's birth weight. When examining over 10,000 Norwegian live singleton births, Magnus and colleagues determined that more than 70% of variation in infant birth weight was accounted for by genetics (Magnus, 1984; Magnus, Beg, Bjerkedal & Nance, 1984). However, a more recent estimate posits that closer to 50% of variation in birth weight is accounted for by genes in a sample of 100,000 Norwegian infants (Lunde, Melve, Gjessing, Skjærven & Irgens, 2007).

These data suggest that between 30% and 50% of the variation in birth weight is due to environmental factors. Magnus et al. (1984) specifically found that lower parental socio-economic status (SES) was associated with decreased birth weight. It is likely that low SES acts indirectly on birth weight and gestational age through greater toxicity in the environment and limited access to health services (Kogan, 1995). In a meta-analysis of birth weight determinants, Kramer (1987) finds evidence for this hypothesis. Low SES and non-white racial identity was correlated with decreased birth weight. Kramer theorizes that this association is indirect, with birth weight directly impacted by increased alcohol consumption, increased maternal cigarette smoking, increased illness morbidity, lower pre-pregnancy weight, younger maternal age, worse quality prenatal and antenatal care, lower caloric intake during pregnancy and increased environmental toxins.

Maternal stress is also associated with birth weight and gestational age, albeit to a lesser degree than exogenous non-genetic predictors. The specific type of stress experienced moderates the relation between stress and birth weight/gestational age. Bussières et al. (2015), in a meta-analysis of over 6 million births, found that life event stress was trivially associated with birth weight ($d = -.03$), though maternity-specific stress was moderately associated with birth weight ($d = -.25$). The researchers hypothesize that maternity-specific stress may be a marker for maternal characteristics associated with low birth weight (such that more difficult pregnancies are likely more stressful and that women with previous difficult childbirth experiences are likely to be more concerned with troubles in their current pregnancy). Bussières et al. (2015) also found that the association between stress and birth weight was moderated by risk status (maternal age, socio-economic status, pre-existing physical conditions), such that larger effects were observed for at-risk populations than low-risk populations.

The Health Consequences of Birth Weight and Gestational Age

A likely reason for the extensive body of research on birth weight and gestational age are their demonstrated links to poor health. Children born early or at low birth weight are at greater risk for morbidity of many illnesses and general mortality (Hack et al., 1995). Children born at ELBW are at an immediate disadvantage, showing increased neurodevelopmental delay at 18 through 24 months (Vohr et al., 2004). Deficits remain in middle childhood, with children born LBW, VLBW and LBW exhibiting greater overall illness morbidity and greater difficulty with daily living functions at ages 8-10 years (McCormick, Brooks-Gunn, Workman-Daniels, Turner & Peckham, 1992).

Meta-analytic evidence has demonstrated that LBW status has deleterious effects on cardiovascular functioning, obesity and mortality throughout the lifespan. Examining over 36,000 deaths of individuals between the ages of 15 and 80 years, Risnes et al. (2011) found that birth weight below the normative range was positively associated with earlier overall mortality and cardiovascular disease, with the lowest birth weights seeing the greatest incidence. Conversely, Yu et al., (2011) found that among studies using participants aged 1-75 years, HBW was associated with greater obesity, although evidence for an association between LBW and decreased obesity risk was inconclusive.

The Cognitive Consequences of Birth Weight and Gestational Age

The majority of the research on birth weight and later life psychological outcomes has examined the relative cognitive functioning of children born at below normal levels of birth weight compared to normal birth weight. The strongest effects are observed when comparing children born in the normative range to children who are born at ELBW and VLBW.

There is extensive evidence for decreased cognitive functioning in middle childhood among children born ELBW and VLBW. Saigal, Szatmari, Rosenbaum, Campbell and King (1991) found that 8-year-old Ontarian children born ELBW scored significantly lower on every single measure of cognitive function when compared to regional, gender and class matched controls, including a mean 13 points worse on full-scale IQ. Anderson and Doyle (2003) found similar patterns in an Australian sample at age 9 years, with children who were born ELBW scoring lower than matched controls on all domains of academic achievement and verbal ability tests, including a mean 9 points worse on full scale IQ. Both Anderson and Doyle (2003) and Saigal et al. (1991) caution that even though controls were matched on social class, region and gender, the parents of ELBW infants had lower education and were less likely to be married at the time of birth. In a Cleveland-area sample of children aged 11 years, Taylor, Klein, Minich and Hack (2000) found that categorically-measured birth weight was associated with cognitive ability, school performance and recall, such that ELBW infants performed the worst, followed by VLBW infants, and finally NBW infants. Children born ELBW scored a mean 21 points lower than children born NBW and a mean 11 points lower than children-born VLBW on standardized measures of cognitive ability. This stepwise function of categorically measured birth weight on IQ is also supported by McCormick et al. (1992) among children aged 8-10 years born NBW, LBW and VLBW.

Finally, the differences between infants born at VLBW and NBW may extend into adulthood. Hack et al. (2002) compared participants born at VLBW and NBW from a (different) Cleveland-area sample on high school graduation rates and IQ. 20-year olds born VLBW were less likely to graduate from high school and showed a mean difference of 5 points on full scale IQ, with both effects being stronger for men than for women.

There is clear evidence that people born at ELBW and VLBW are cognitively disadvantaged compared to people born at NBW. However, each of the studies listed above provides a single measurement point. Studies that examine multiple time-points, especially across a wider range of birth weight, provide the clearest sense of the persistence of associations between birth weight and cognitive functioning.

Strauss (2000) followed over 1,000 infants born below the 5^{th} percentile for birth weight and assessed their academic performance at ages 5, 10, 16 and 26. At age 5, children born NBW outperformed their LBW peers in all four measures of academic success. However, at age 10, children born LBW only lagged behind in 2 of 3 academic measures, and in only 1 of 2 academic measures at age 16. At age 26, there were no observed differences in unemployment or self-reported standard of living, although participants born LBW did have less prestigious jobs and lower income than participants born NBW.

Boardman et al. (2002) assessed reading and mathematics ability among a national sample of children born at VLBW, LBW and NBW every two years between the age of 6 and 14. In comparisons between children born at VLBW and NBW, differences in both math and reading level were pronounced and did not attenuate with time. However, differences between children born at LBW and NBW, while statistically significant, diminished over the duration of the 8-year study. Differences between LBW and NBW children were eclipsed in predictive power over time by racial differences, suggesting that interventions would be much more effective by serving black children rather than LBW children.

Richards et al. (2001) report similar findings to Boardman et al. (2002) with regards to relatively greater differences between participants born VLBW compared to NBW than LBW compared to NBW. Measuring a British cohort for decades, the researchers found consistently lower cognitive ability (d =.23 to d =.33) for children born at VLBW than NBW at ages 8, 11, 15 and 26 years. Additionally, they found marginal differences in cognitive functioning at all ages *within* the normal range of birth weight (d = .03 to d = .13). Contrasting with the findings of Boardman et al. (2002), Richards et al. found no attenuation of differences over time within either the VLBW group or for differences within the rage of NBW. One explanation for these may be medical advances that developed between the birth years of the two cohorts (a difference of approximately 33 years).

These three longitudinal findings, when considered together, allow for compelling alternative hypotheses regarding the endurance of associations between birth weight and cognitive functioning. In all three studies, there are strong early associations between birth weight and cognitive performance. However, in one case those effects endure (Richards et al., 2001), in another the effects decline but do not asymptote to zero by age 14 years (Boardman et al., 2002) and in another diminish almost completely by age 26 years (Strauss, 2000). Considering that these studies all measured the differences between LBW and NBW, they provide evidence for either a revisionist or enduring effects model of development within the normative range of birth weight.

Quantitative meta-analyses may also shed light on whether the effect of being born below the normal range of birth weight endures or diminishes overtime. Although the majority of the studies cited in these meta-analyses are not longitudinal, they sample children of many ages, which support the notion that low birth weight predicts cognitive functioning throughout the lifespan. Examining 15 studies featuring infants of varying birth weights below the normal range matched with NBW controls, Bhutta et al., (2002) found that children born LBW differed in IQ from children born NBW by a mean of 10.9 points. There was no attenuation of this effect across their observed age range of 5 and 12 years, and differences in IQ were equally attributable to low birth weight and early gestational age.

This decreased cognitive functioning may be a result of disrupted brain development. De Kieviet, Zotebier, Van Elburg, Vermeulen and Oosterlaan (2012) meta-analyzed fifteen MRI studies comparing children born VLBW to children born at NBW. Across total brain volume, white matter, and grey matter, the researchers found strong effects of birth weight (d = .53 to .62). Like Bhutta et al. (2002), they saw no attenuation of these differences, examining children aged 8 through 18 years.

Gestational age also independently predicts cognitive outcomes above beyond birth weight, although this effect may be curvilinear and moderated by risk status. Yang, Platt and Kramer (2011) measured the impact of gestational age within the normative range (37-42 weeks) on intelligence with a sample of Belarusian children born at NBW. At age 6.5 years, gestational age showed a curvilinear relation with intelligence, such that IQ peaked for children born at 40 weeks. The three-week difference between 37 weeks and 40 weeks resulted in a difference of 1.7 IQ points, whereas the three-week difference between 40 weeks and 43 weeks resulted in a difference of 6.0 IQ points, controlling for prenatal substance use and SES.

Ekeus, Lindstrom, Lindbald, Rasmussen and Hjern (2010) extended these findings into early adulthood and outside the normative range of gestational age. Examining a national sample of nearly 120,000 Swedish men, they compared the cognitive competence of participants born at NGA, EGA, and EEGA at age 18-19 years. Like Yang et al. (2011), they found a non-linear relation, although in this case, a much stronger drop in cognitive functioning between EEGA and EGA than between EGA and NGA, mirroring patterns of birth weight observed by Boardman et al. (2002) and Richards et al. (2001). However, like Bussieres et al. (2015), Ekeus et al.'s (2010) findings suggested a dual risk pattern in which the relation between gestational age and cognitive functioning was stronger among low SES participants. This was particularly the case when comparing participants who were EGA and NGA, as well as when looking at variations in cognitive outcomes *within* the NGA group.

Finally, Kerr-Wilson, MacKay, Smith and Pell (2011) provide meta-analytic evidence linking cognitive functioning and gestational age within and beyond the normative spectrum. Examining evidence from 3500 pre-term of varying gestational age and 3500 full term infants, the researchers found a linear pattern of IQ differences between early gestational age and normal gestational age. Being born at 25 weeks resulted in a mean 16-point difference in IQ when compared to NGA, whereas being born at 35 weeks resulted in a mean 8-point difference in when compared to NGA. The disparity between the curvilinear findings between Kerr-Wilson et al. (2011) and Ekeus et al. (2010) are likely due to examining only differences between EGA and NGA and not variation within NGA.

As mentioned above, the majority of evidence provided compares children born at low birth weight to children born at normal birth weight. However, cognitive functioning is also predicted by birth weight for children born *within* the normative range. This is an important finding, given that it applies to the majority of infants, and also allows for the separation of birth weight from comorbidity that affects people born at VLBW and ELBW. Shenkin, Starr and Deary (2004) provide a thorough accounting of the literature examining how variation within the normative range of birth weight and gestational age is associated with cognitive functioning. Narratively reviewing six studies with a cumulative sample size of over 50,000 participants between the ages of 7 and 33, Shenkin et al. (2004) describe a consistent and positive association between birth weight and cognitive ability, with raw correlations ranging between r = .10 to .19. Controlling for demographic factors, paternal characteristics and gestational age, standardized coefficients ranged from β = .15 to β = .27, demonstrating that birth weight accounted for variance independent of race and class, although effect sizes of demographic predictors reliably exceeded birth weight. These findings, along with Yang et al. (2011), provide the strongest evidence to date for enduring effects of birth weight and gestational age within the normative rage and across the lifespan.

The Social Consequences of Birth Weight and Gestational Age

Being born early or at lower than normal birth weight is not only associated with cognitive functioning; it also is also linked to social competence. As with cognitive functioning, the majority of research regarding the social impact of birth weight examines children born below the normal range with matched controls. Additionally, the most commonly assessed social-emotional outcome of low birth weight is diagnosis of psychopathology, with evidence consistently supporting the association of below-normal birth weight with internalizing symptoms and attention deficit hyperactivity disorder (ADHD).

Several studies comparing children born early or low-weight to children born within the normative range have shown differences in internalizing but not externalizing symptoms. Farooqi, Hägglöf, Sedin, Gothefors and Serenius (2007) compared EEGA infants and NGA infants at 11 years old and found that children born extremely early had more total psychiatric problems, both as reported by parents using the Child Behavior Check List (CBCL) and by teachers using the Teacher Report Form (TRF). Domain-specific broadband scores indicated that children born EEGA had internalizing symptoms, but not increased externalizing symptoms. This greater risk for internalizing psychopathology continues into adulthood. Women born VLBW report higher incidence of internalizing, but not externalizing, symptoms than NBW peers at age 20 years (Hack et al., 2004). Both women and men born ELBW report greater incidence of internalizing, but not externalizing, behavior at age 22-26 years (Boyle et al., 2011). Contrary to these findings, Indredavik, Vik, Heyerdahl, Kulseng and Brubakk found increased internalizing *and* externalizing behavior at age 14 years among children born VLBW, although only when using parent report. Adolescent self-report measures yielded no psychopathology differences between children born VLBW and NBW.

Longitudinal studies have also demonstrated consistently that LBW infants have increased incidence of ADHD in childhood. Breslau et al. (1996) showed that among

Michigander 6 year olds, children born LBW experienced more ADHD symptoms compared to children born NBW, and these differences were greater in the predominantly black and low-class participants than white suburban participants, mirroring dual risk patterns in cognitive functioning. Scott et al. (2012) also found greater incidence of ADHD and behavior problems when comparing 6-year old children born ELBW to children born NBW using both parent and teacher ratings.

There is also meta-analytic evidence demonstrating the predictive power of low birth weight on internalizing symptoms and attention problems. Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever and Oosterlaan (2009) found greater incidence of teacher-reported internalizing symptoms, self- and teacher-reported attention problems and decreased cognitive function when comparing around 4000 EEGA/VLBW infants to 3200 NBW infants. Culled from studies measuring participants aged 9-23 years, there was no attenuation of effect as a function of age. Bhutta et al. (2002) also found greater incidence of externalizing behavior and ADHD in children aged 5-14 years who were born EGA.

There is also empirical support for non-clinical variation in social competence as a function of birth weight lower than the normal range. Most of these studies examine the difference between children born VLBW and children born NBW, focusing on parent and teacher reports of social competence. These differences have been studied across a variety of samples and over a fairly large range of ages, although very few studies have examined the persistence of these differences longitudinally.

Differences in social competence have been observed in children as young as 7 years, with children born VLBW displaying lower social competence than children born

NBW as rated by parents and teachers (Hoy et al., 1992; Nadeau, Boivin, Tessier, Lefebvre & Robaey, 2011; Ross, Lipper & Auld, 1990). These associations have been found to be robust to SES and IQ covariates (Hoy et al., 1992) and moderated by SES (Ross et al., 1990). McCormick et al. (1996) also find differences in social competence as the result of birth weight in 8-10 year olds examining multiple categories of LBW, and Farooqi et al. (2007) report lowered social competence for children born EEGA as compared to children born NGA at age 10-12 years. Differences in social competence continue into early adolescence, with children born NBW outperforming children born VLBW via self-report, parent report (Indredavik et al., 2005) and teacher report (Rickards, Kelly, Doyle & Callanan, 2001). However, Strauss (2000) found no difference between children born LBW and NBW in number of friends or social functioning at age 16, or in marriage or social status at age 26, suggesting these effects may dissipate in late adolescence or early adulthood.

To date, there are no studies examining differences in social functioning as a result of birth weight within the normal range. However, Shenkin's (2004) review of cognitive outcomes lends support to this hypothesis. There is evidence of variation in cognitive functioning as a function of differences in birth weight within the normative range and demonstrated associations between social competence and cognitive capacity (Ford, 1982; Lemersie & Arsenio, 2000; Riggs, Jahromi, Razza, Dilworth-Bar & Mueller, 2006; Wentzel, 2001). This evidence, when combined with support for lower social competence among children born LBW between ages 7 and 14 years, suggest that variation within normative birth weight and gestational age may be associated with childhood and adolescent social functioning.

Plausible Mechanisms of Decreased Functioning As a Consequence of Birth Weight and Gestational Age

There may be indirect paths between birth weight/gestational age and cognitive/social functioning. Some plausible mechanisms identified in the extant literature are differential early brain development and differential caregiver interaction. Differential brain development results in decreased cognitive functioning and executive control, resulting in decreased ability to adapt to complex social situations. In particular, early cognitive delay could impact children's ability to practice social skills, placing them on a trajectory of lower social fluency.

In general, lower cognitive functioning is moderately associated with social competence (Razza & Blair, 2009; Riggs et al., 2006). There may be a mediational path wherein birth weight predicts neurological growth, which in turn predicts cognitive functioning, which then predicts social functioning. Clark, Woodward, Norwood and Moor (2008) found that among pre-term infants, one of the primary predictors of self-regulation at age 4 was abnormal brain development. De Kieviet et al. (2012) provided meta-analytic evidence for lower total brain volume among LBW/EGA infants, adding support for this mediational path.

There are also demonstrated paths between delayed cognitive development and social deficits in children born EGA. Delobel-Ayoub et al. (2009) found that children born VEGA showed more behavioral problems at age 5, and these behavioral problems were strongly associated with lower cognitive functioning. Differences in cognitive function between children born EGA and VEGA have also been shown to mediate the relation between gestational age and social functioning in kindergarten (Maupin & Fine, 2014). Intelligence continues to mediate the relation between EGA and increased social and emotional problems at age 7 years (Nadeau, Boivin, Tessier, Lefebvre & Robaey, 2001) and from ages 9-11 years (Loe, Lee, Luna & Feidman, 2011). However, in a sample of children aged 9-16 years born EEGA and VEGA, Conrad, Richman, Lindgren and Nopoulos (2010) found that intelligence did not mediate differences in internalizing symptoms and attention problems as a function of birth weight, providing evidence of a direct path between the birth weight and social functioning.

Mothers of lower birth weight infants may also display differential maternal care as a result of their child's difficulties, which could have long-lasting impact on social functioning. Mothers of low birth weight and early gestational age infants show increased overprotective and controlling parenting, decreased maternal touch, and lower levels of early mother-infant synchrony. These caregiving patterns may be expected to result in lower social competence as a result of attachment disruptions and decreased opportunities for socialization with peers.

Parents of low birth weight children may engage in overprotective parenting, reducing their children's chances for social interaction, which puts them at an early social disadvantage. Singer et al. (1999) found that mothers of VLBW children suffered greater distress than mothers of NBW infants, which could lead to overprotective parenting. Hoy et al. (2002) speculated that worry about VLBW children's health and well-being could lead to restrictive parenting, which would explain observed decreases in social competence among VLBW children across socioeconomic classes. Differential interaction with caregivers for children born EEGA persists until at least age 8 years, with mothers of children born EEGA showing decreased sensitivity and increased control in semi-structured interactions than the mothers of NGA children; these caregiving differences may limit EEGA children's ability to develop the autonomy needed for effective social interaction (Jaekel, Wolke & Chernova, 2012).

Children who are born very small or very early may also receive less touch during their very early life, given their fragility and high incidence of post-natal illness. This decrease in touch may lead to insecure attachment with caregivers, disrupting general working models of social interaction. Indeed, Weiss et al. (2001) found that lower levels of touch in the first three months among infants born VLBW to LBW predicted behavioral problems at age 2. These concerns, however, may not be as relevant to children within normal range of birth weight.

Differences in early neuromotor development based on birth weight might also lead to differential caregiver interaction. Children born LBW may not have an age-typical capacity to respond to parents' cues, resulting in decreased mother-child synchrony with potential downstream effects on attachment organization. Examining interactions between 0-12 month infants and their mothers, Crnic, Ragozin, Greenberg, Robison and Basham (1983) found that, compared to NGA infants, EGA infants were less dynamic and responsive to their mother's tactile and facial cues, leading to decreased mother-infant synchrony. Bakeman and Brown (1980) found a similar pattern between EGA and NGA infants during their first year, but found that maternal sensitivity at 20 months successfully buffered the difference between EGA and NGA infants' social ability at 36 months, suggesting that attentive and sensitive mothers may be able to overcome early interactive asymmetry. This mother-child asynchrony is associated with decreased positive affect intensity in infancy, at least among infants born EEGA (Sansavani et al., 2015). These deficits in early positive affect may reduce children's later ability to master stage-salient skills required for effective social interaction.

Plausible Moderators of the Association between Birth Weight/Gestational Age and Social/Cognitive Functioning

Across the birth weight and gestational age literature, there is consistent support for the moderating influence of socio-economic status on cognitive and social outcomes. Research examining both variables has revealed a dual-risk pattern, such that children with low birth weight *and* low SES are most likely to have deficits because of limited access to resources that may remediate early cognitive or social impairments.

Differences in cognitive functioning between children born EGA/LBW and NGA/NBW are more pronounced among low SES families, especially early in life. Fan et al. (2013) and Cserjesi et al. (2012) observed greater differences between NGA and EGA in cognitive functioning among low SES 7-year olds compared to middle/high income peers. SES continues to moderate this relation into adolescence (Boardman et al., 2013) and early adulthood (Ekeus et al., 2010). Links between natal variances and social functioning are also moderated by SES from age 6 through 10 years (Fan et al., 2013; McCormick et al., 1992; Ross et al., 1990).

Just as high-risk environments may amplify differences in birth weight, sensitive parenting may buffer the negative social effects of low birth weight. Children born at lower birth weight who receive high-quality parenting may see their differences in relation to higher birth weight children decline over time, as their parents scaffold their social development. Clark et al. (2008) found that sensitive maternal care and brain development equally predicted social and emotional well-being at 2 years of age among children born EEGA and VEGA. Maupin and Fine (2014) also found that sensitive parenting moderated the relation between gestational age at age 2, which in turn predicted better social functioning at age 4. As discussed above, Bakeman and Brown (1980) also found that sensitive care moderated the relation between birth weight and social ability. In a longitudinal analysis, sensitive parenting was most strongly associated with social competence among children born at VLBW than NBW at ages 3-10 years (Smith, Landry & Swank, 2005). These effects may extend into adolescences, with sensitive parenting acting as a protective factor against the negative effect of VEGA on academic achievement in 13 year olds (Wolke, Jaekel, Hall & Baumann, 2013).

The positive impact of interventions based upon improving mother-infant synchrony demonstrates the potential for buffering the adverse consequences of low birth weight. Spiker, Ferguson and Brooks-Gunn (1993) found that an intervention for parents of LBW infants focused on learning activities and problem-solving games lead to improved maternal care, child competence, and dyadic synchrony. An intervention focusing on recognizing distress and responding sensitively conducted by Rauh, Achenbach, Nurcombe, Howell and Teti (1988) showed that cognitive differences between LBW and NBW children can be effectively reduced. A LBW intervention group, a LBW control group, and a NBW control group were measured periodically from birth to age 4, with the intervention occurring over the first 90 days after birth. Although both LBW groups showed initial cognitive deficits compared to the NBW group, the differences between the intervention LBW group and NBW declined to zero over time, whereas the differences in the LBW control group and the NBW group increased over time.

Alternative Models of Development and Their Application to Birth Weight and Gestational Age

There is compelling evidence for non-trivial associations between birth weight/ gestational age and cognitive/social functioning, especially early in development. However, the enduring legacy of birth weight and gestational age within the normative range has never been formally tested. In order to examine the persistence of gestational age/birth weight's associations with cognitive and social functioning, I will test two alternative models of developmental influence: the enduring effects model vs. the revisionist model.

Roisman and Fraley (2013) specify one way in which developmental psychologists can formally examine these two contrasting assumptions of development. In particular, they focus on two approaches with shared assumptions but differing hypotheses. The *revisionist* model of social development states that early experiences proximately impact behavior but, as a child grows older and acquires new information, competencies, and relationships, these novel experiences eventually overwrite associations between earlier factors and later outcomes. Thus, as people age, the net association between early experience and later behavior asymptotes to zero. An apt metaphor for this view of development is a tape recorder (Fraley, Roisman & Haltigan 2013; Kagan, 1980). In an attempt to update this metaphor, I imagine revisionist models of development as a flash drive: relations between early experience and behavior are saved permanently and concretely, and can be accessed as long as they remain on the flash drive. However, as new information is added to the drive, old associations are overwritten in favor of more recent and pressing data.

Like the *revisionist effects* model, The *enduring effects* model of development also assumes that early factors impact proximal behavior and more recent predictors impact later behavior. However, it also states that, although associations between focal early factors decrease initially in magnitude over time, they eventually asymptote to some non-zero value. Thus, early factors continue to predict later outcomes directly. According to this view, development can be viewed as a cloud storage system. Early information may make up a smaller portion of the total allotted space, but is never completely lost.

Both perspectives assume that some of the legacy of early experience is transmitted indirectly through proximal experience. For example, birth weight may impact social functioning at age 2, which in turn impacts social functioning at age 4. The revisionist perspective predicts that this path, in addition to other proximal factors, should completely account for variance in social functioning at age 4. However, the enduring effects model states that birth weight will independently affect social functioning at age 4, above and beyond the impact of social functioning at age 2.

Prospective longitudinal measurement is needed to test these two competing theories of development. Because birth weight is measured and recorded in almost all US hospital births, it would simple to assess birth weight retrospectively and then compare children of different birth weight in a cross-sectional manner. However, an association between birth weight and cognitive functioning of $r = .15$ at age 5 could be evidence for either conception of development. Without information about the magnitude of the association both at earlier and later time points, researchers cannot determine whether this association is diminishing to zero or remaining stable over time.

These pathways of influence can be formally tested using structural equation modeling (see Figure 1 for an example). Both revisionist and enduring effects models state that birth weight/gestational age should impact the earliest measurements of cognitive and social functioning (Path A) and that early cognitive/social functioning should impact later cognitive/social functioning (Path C). However, the revisionist model sets paths between birth weight/gestational age and later cognitive/social functioning to zero, whereas the enduring effects model allows them to vary with values above zero. Tests of model fit can then be compared to determine which model best accounts of the observed data.

This method for comparing alterative theories of development has been previously applied to cognitive and social functioning. Fraley et al. (2013) and Raby et al. (2015) examined how maternal sensitivity impacts academic achievement and social competence to age 15 in the SECCYD and to age 32 in the MLSRA, respectively. In both investigations, the enduring effects model better accounted for variation in both domains. Raby et al. (in press) also tested the enduring effects vs. revisionist model on academic achievement and social competence, with childhood abuse and neglect as the focal predictive variable. They found that the revisionist model better predicted academic performance, whereas the enduring effects model better predicted social competence. Finally, Haltigan et al. (2013) employed this approach to examine the nature of maternal sensitivity's associations with psychopathology in the SECCYD, finding evidence for enduring effects when examining teacher reports of psychopathology, but results more consistent with a revisionist perspective when using maternal reports.

Birth weight and gestational age represent a particularly strong test of the enduring effects model of development because these factors represent the earliest post-natal information about a person. If birth weight and gestational age exhibit enduring associations with cognitive/social functioning beyond more proximal social/cognitive measures, this would provide theoretical support for the essentiality of early factors across development and inform practitioners concerned about the long-term impact surrounding the timing of childbirth.

The Current Study

There is ample evidence that low birth weight and early gestational age is associated with decreased cognitive and social functioning. This research has primarily focused on children born outside the normative range of weight/gestational age, and longitudinal investigations of this link have not yet determined whether birth weight/gestational age continue to be directly correlated with cognitive and social functioning across time.

In order to test these formal models, I will leverage data from the MLSRA to conduct a test of the potentially enduring association between birth weight and functioning in later life. The MLSRA (Sroufe, Egeland, Carlson & Collins, 2005) is a prospective longitudinal study of an initially socioeconomically at-risk sample on which assessments have been made from birth to age 39. The MLSRA has repeated measurements of cognitive functioning until age 34 years and reports of social competence assessed through age 26 years.

My hypotheses are contingent on one another in that, if there are no bivariate associations between birth weight/gestational age and cognitive/social functioning (especially at the earliest time points), it is unreasonable to test an enduring effects vs. revisionist model. For the educational purposes of this dissertation, I will still compare Enduring Effects vs. Revisionist Effects models but conclude that there are no early associations. I will investigate cognitive and social functioning separately in order to test differential functioning based on natal variables in each domain. Based on Shenkin et al.'s (2004) review, I predict (*Hypothesis 1*) that there will be associations between birth weight/gestational age and early cognitive functioning. I additionally predict (*Hypothesis 2)*, based on evidence from Bhutta et al. (2002), De Kievit et al. (2012), and Richards (2001), that the enduring effects model will better account for the associations between birth weight/gestational age and later cognitive functioning. There is, however, evidence from Boardman et al. (2002), Kerr-Wilson et al. (2011), and Strauss et al. (2000) that associations diminish over time, favoring the revisionist effects model. Thus, with regard to social functioning, I predicted (*Hypothesis 3)* that there will be associations between birth weight/gestational age and early social functioning. Although I hypothesized that the associations between birth weight/gestational age and social functioning are non-trivial, there is little investigation of these correlations within the normative range. I am more confident in the existence of associations between birth weight/gestational age and cognitive functioning than I am social functioning. Finally, I predicted (*Hypothesis 4)* that these early associations between birth weight/gestational age and social functioning should diminish to zero over time and the revisionist model will best explain these relations.

Additionally, after my initial analyses, I conducted four post-hoc model comparisons examining cognitive functioning predicted by birth weight while controlling for gestational age, similar to research examining infants born small for gestational age (Lee et al., 2003; Saenger, Czernichow, Hughes & Reiter, 2007). These tests were exploratory and had no a priori hypothesis.

Method

Participants

Participants were from the Minnesota Longitudinal Study of Risk and Adaptation (MLSRA; Sroufe et al., 2005), an ongoing longitudinal study of development from infancy to adulthood. Between 1975 and 1977, pregnant mothers who were living below the poverty line and receiving free prenatal services through the local health department in Minneapolis, Minnesota, were recruited. At the time of their child's birth, 48% of the mothers were teenagers, 65% were single, and 42% had completed less than a high school education. The analytic sample included all participants who have recorded birth weight and gestational age *(N* =252).

Birth weight: Birth weight was measured in grams. Birth weight of MLSRA participants ranged from 1500g-4720g, with a mean of 3261g, a median of 3260g, and a standard deviation of 541g.

Gestational Age: Gestational age was measured in weeks. Gestational age of MLSRA participants ranged from 35 to 44 weeks, with a mean of 39.7 weeks, a median of 40 weeks, and a standard deviation of 1.6 weeks.

Assessments of cognitive functioning: Cognitive functioning was assessed using standardized measures of intellectual ability and academic achievement. At age 24 months, participants were assessed via the Bayley Scales of Infant Development (BSID; Bayley, 1969). At age 42 months, participants were assessed via the Preschool Language

Scale (Zimmerman, Pond & Steiner, 1979). At age 64 months, participants were assessed via the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 1967). From grades 1, 2, 3 and 6, participants were assessed via the Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1970). At age 16 years, participants were assessed via the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R; Woodcock, Johnson & Mather, 1990). At ages 23 years, 26 years, 32 years and 34 years, educational attainment was measured in years of education via an ordinal scale.

Assessments of social functioning: Social competence during childhood and adolescence was assessed using teachers' rankings of each child's competence with peers during kindergarten; grades 1, 2, 3, and 6 and at age 16. Teachers were asked to rank all the students in their classrooms according to how well each student matched developmentally-appropriate behavioral descriptions of social competence. Children who most closely resembling the criterion description were ranked near the top. Children's rankings in the various classrooms were then standardized by dividing their rank by the number of students in their class (for more information, see Sroufe et al., 1999). At ages 23 years and 32 years, participants took part in semi-structured interviews about their history of romantic relationships. Trained coders rated the interviews for effectiveness of romantic engagement, with participants who described histories of close, trusting, healthy relationships scored highly on this measure of romantic competence.

Demographic measures: Demographic covariates were selected based on their known impact on health outcomes and their standard inclusion in prior MLSRA investigations (e.g., Raby, Roisman, Simpson, Collins & Steele, 2015; Sroufe, Egeland, Carlson & Collins, 2005). These variables are: sex (1 = female, 0 = male); race (1 = White/non-Hispanic, 0 = otherwise); maternal socioeconomic status (SES) as measured by the Duncan Socioeconomic Index (Duncan, 1961); and maternal education as measured by highest level of education attained. The Duncan Socioeconomic Index, which assesses occupational prestige and family income, was assessed prenatally. Maternal education represented the mother's highest level of attained education and was also assessed prenatally.

These variables allow for a total of 4 different sets of model comparisons: (1) birth weight predicting cognitive outcomes in the MLSRA; (2) gestational age predicting cognitive outcomes in the MLSRA; (3) birth weight predicting social outcomes in the MLSRA; (4) gestational age predicting social outcomes in the MLSRA. Each set will then test four different models.

Comparing Models of Development

The first step in determining the enduring or diminishing effect of birth weight and gestational age on cognitive and social functioning is to determine whether or not there are associations between the predictors and the earliest measured assessment of cognitive functioning and social competence.

I will report each set of model comparisons in four parts, for a total of 16 comparisons. In the first part, I will compare a model that includes direct and indirect paths between the predictor and the outcome (Enduring Effects) with a model that includes only indirect paths between the predictor on later functioning (Revisionist Effects). In the second part, I will compare the relative fit of the Enduring and Revisionist models predicting cognitive outcomes, after including relevant demographic covariates.

All variables will be standardized prior to conducting the analyses. As a result, all beta coefficients will represent standardized effects.

In each set of analyses, I will test the absolute fit of the models using Comparative Fit Index (CFI), Standardized Root Mean Square Residual (SRMR) and Root Mean Square Error of Approximation. For the CFI, a value greater than .90 is considered good fit (Hooper, Coughlan, & Mullen, 2008) For the SRMR, values of less than .08 are considered to be good model fit (Kenny, 2015). For the RMSEA, model fit is considered to be excellent, good, mediocre and poor at .01, .05, .08 and .10 respectively (Kenny, 2015). I will then compare whether the models differ significantly in fit via a chi-square difference test. Non-significant differences between the two models favor the less-complex Revisionist Effects model, in that the additional paths do not improve model fit.

Each set of analyses will test whether an Enduring Effects or a Revisionist Effects model best explains the relation between birth weight/gestational age and cognitive functioning over time. The Revisionist model is nested within the Enduring Effects model (see Figure 1). Specifically, by fixing paths from the predictor to the later outcome variables to 0.00 (the paths labeled *b*), this model will test whether birth weight/gestational age is directly associated with cognitive/social functioning early in life, but not later. In the enduring effects model, the direct paths (i.e., the *b* paths) are constrained to be equal to one another. Although this constraint is not a theoretical necessity, it provides the most conservative test of the Enduring Effects model because it prevents the model from over-fitting natural variation in the data (Fraley et al., 2013). The parameter *a* is not constrained to equal the *b paths* because the association between the predictor and *Assessment 1* (at twenty-four months cognitive functioning and at kindergarten for social functioning) is exclusively a direct effect, whereas the association between the predictor and subsequent assessments is a combination of direct and indirect effects.

I will next examine whether birth weight/gestational age have enduring effects on cognitive/social functioning after controlling for four potential confounds: child sex, child ethnicity, maternal education, and maternal socioeconomic status. In these analyses, I will model the effects of the potential confounds as if they were enduring in the manner assumed by the Enduring Effects model. This is a conservative test of the Enduring Effects model, in that it assumes that the potential confounds have enduring effects as well (see Raby et al., 2015, for details). In addition, tests of Revisionist models will involve constraining the value of the paths from birth weight/gestational age to cognitive/social functioning to zero, while continuing to allow enduring effects paths for each of the covariates. This specification of the Revisionist model is revisionist with respect to the way it treats only the effects of birth weight/gestational age; the model allows for the possibility that the various covariates have unique and enduring effects on cognition/social competence.

Finally, I will compare models that include second-order stability paths. These paths "leapfrog" along outcomes (e.g. paths from Assessment 1 to Assessment 3 or from Assessment 2 to Assessment 4), and often improve absolute model fit. These paths are included to measure stability in the outcome variable that is unaccounted for by the association with the preceding assessment. All of these data analytic procedures mirror prior tests between these models.

Previous tests of this framework have also included controlling for ongoing measurement of the predictor over time (e.g. maternal sensitivity; see Fraley et al., 2013). Because birth weight and gestational age are not processes that continue past birth, this dissertation will not investigate these paths.

I believe that results supporting either the revisionist or enduring effects model will provide useful insight into the long-term effects of birth weight within the normative range. There is ample evidence showing the negative outcomes associated with being born very early or very small. Knowing whether a few weeks or dozens of grams have enduring, non-trivial psychological correlates can assist practitioners in making decisions with mothers about inducing labor or waiting longer. If birth weight and gestational age do in fact have enduring effects, researchers can adjust the focus of competency interventions; if there are no enduring effects, researchers can be more confident in isolating other risk factors or focusing on catch-up in infancy and early childhood.

Results

Associations Between Birth Weight/Gestational Age and Cognitive/Social Functioning

Gestational age is moderately correlated with birth weight ($r = .52$, $p < .001$). Birth weight was positively associated with cognitive functioning at the first eight assessments, $r = .17$ to $.23$, $p = .025$ to $.003$, each of which was measured via cognitive achievement test. Birth weight was not associated with cognitive functioning in assessments nine through twelve (indexed via educational attainment), $r = .06$-$.12$, $p = .14$-$.43$. Gestational age was not associated with cognitive functioning for any of the twelve assessments, $r = -.11$ to $.11$, $p = .13$ to $.62$. These associations are detailed in Table 1.

Birth weight was not associated with social competence in any of the eight assessments, $r = -.11$ to $.05$, $p = .14$ to $.99$. Gestational age was also not associated with social competence at any of the eight assessments, $r = -.15$ to $.01$, $p = .05$ to $.94$. These associations are detailed in Table 2.

Associations Between Outcome Variables

Each assessment of cognitive functioning was positively associated with every other assessment of cognitive functioning, with the exception of the first assessment (24-month Bayley Index) and last assessment (34-year educational attainment), $r = .14$, $p = .093$. All other correlations range in magnitude from $r = .17$ to $.91$, $p < .05$ (see Table 1). Similarly, each assessment of social competence was associated with every other assessment of social competence except for the fourth assessment (Grade 3 teacher rating) and the seventh assessment (23-year relationship engagement), $r = .09$, $p = .24$. All other correlations range in magnitude from $r = .18$ to $.54$, $p < .05$ (see Table 2).

Associations Between Demographic Covariates and Cognitive/Social Functioning

Cognitive functioning was positively and significantly associated with mother's pre-natal maternal education at all twelve assessments, $r = .24$ to $.39$, all $p < .001$, such that mothers with more education had children with better cognitive outcomes. Cognitive functioning was also positively and significantly associated with mother's pre-natal socioeconomic status, $r = .18 - .32$, all $p < .03$; as expected, mothers with higher occupational prestige had children with better cognitive outcomes. Race of the participant (being white vs. non-white) was positively associated with cognitive functioning at seven of the first eight assessments, but not the last four assessments (which were indexed via educational attainment). The significant associations ranged from $r = .17$-$.25$, $p < .05$.

Sex of participant (being female vs. male) was positively associated with cognitive functioning at four of the twelve assessments. Thus, participants who were white and female tended to have higher cognitive outcomes compared to their peers (see Table 1).

Similar to cognitive functioning, social competence was positively and significantly associated with mother's pre-natal maternal education at six of eight assessments, $r = .24$ to $.39$, all $p < .001$. Social competence was positively and significantly associated with mother's pre-natal socioeconomic status at three of eight assessments, $r = .18 - .32$, all $p < .03$. Race of the participant (being white vs. non-white) was positively associated with social competence at zero of eight assessments. Sex of participant (being female vs. male) was associated at three of the eight assessments. These associations are detailed in Table 2.

Birth weight and gestational age were not significantly associated with any of the demographic covariates (see Table 1 and 2)

Basic Comparisons Between Enduring Effects and Revisionist models of Birth Weight/Gestational Age Predicting Cognitive Functioning

The first comparison examines whether the revisionist or enduring effects model best fits the data considering only the predictor and outcome variables. The revisionist model is nested within the enduring effects model, with one fewer free parameter. As described above, in the enduring effects model, all paths from birth weight to subsequent (*b* paths) are set to equal one another, rather than being allowed to vary. In neither the Enduring Effects nor Revisionist model was the path from birth weight to the first assessment (or *a* path) fixed.

In the basic birth weight models predicting cognitive functioning, both Enduring Effects and Revisionist Models had acceptable model fit (RMSEA 90% CI = .062-.080, CFI = .948) and the basic Revisionist model (RMSEA 90% CI = .063-.091, CFI = .947). There was there no statistically significant difference between the two models, $\Delta\chi2 = 2.73$, $p = .099$, indicating that the additional *b* parameter included in the Enduring Effects model does not incrementally improve model fit. The direct path between birth weight and the first assessment (*a* path) was estimated at .20, $p = .003$, and direct paths between birth weight and later assessments (the *b* paths) were estimated at .02, $p = .099$ (see Table 3 and Figure 1). This indicates a small-to-medium association between birth weight and cognitive functioning in infancy, and a non-significant enduring effect from birth weight to later cognitive outcomes.

In the basic gestational age model predicting cognitive functioning, both models exhibited good-to-mediocre model fit. There is no statistically significant difference between the basic Enduring Effects model (RMSEA 90% CI = .064-.093, CFI = .945) and the basic Revisionist model (RMSEA 90% CI = .064-.093, CFI = .945), $\Delta\chi2 = 0.98$, $p = .32$. The direct path between gestational age and the first assessment (*a* path) was estimated at .11, $p = .11$, and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.01, $p = .32$ (see Table 4 and Figure 2). Consistent with bivariate findings, this indicates no significant association between gestational age and cognitive outcomes, either in infancy or later in life.

In all basic models investigating cognitive functioning, each indirect path between an assessment of cognitive functioning and the previous assessment was significant, with path estimates ranging from .40-.90, all $p < .001$. This indicates moderate to very strong stability in cognitive functioning from infancy to early adulthood.

Extensions of the Model: Covariates

In the next set of analyses, I compare more complex models incorporating variables that may impact the relations between birth weight/gestational age and cognitive functioning. First, I model demographic variables that have been consistently used in MLSRA investigations: sex of the child, race of the child, mother's prenatal education, and mother's prenatal socio-economic status (indexed via occupational prestige). Like the *b* paths, the relations between demographic variables and cognitive functioning were not forced to zero, but they were held constant across assessments (see Table 3).

Predicting cognitive functioning from birth weight account for demographic covariates, both models demonstrated good-to-mediocre model fit. The Enduring Effects model with demographic covariates (RMSEA = .059-.081, CFI = .929) fits the data significantly better than the Revisionist model with demographic covariates (RMSEA 90% CI = .059-.082, CFI = .928), $\Delta\chi2 = 4.48$, $p = .034$. The direct path between birth weight and the first assessment (*a* path) was estimated at .20, $p = .002$, and direct paths between birth weight and later assessments (the *b* paths) were estimated at .03, $p = .034$ (see Table 3 and Figure 3). This indicates a small-to-medium association between birth weight and cognitive functioning in infancy, with a very small enduring effect linking birth weight and later cognitive outcomes.

Predicting cognitive functioning from gestational age, there was no statistical difference between the Enduring Effects model with demographic covariates (RMSEA =

.059-.082, CFI = .928) and the Revisionist model with demographic covariates (RMSEA 90% CI = .059-.082, CFI = .928), $\Delta\chi2 = .53$, $p = .47$. Again, both models exhibited good-to-mediocre absolute model fit. The direct path between gestational age and the first assessment (*a* path) was estimated at .11, $p = .096$ and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.01, $p = .47$ (see Table 4 and Figure 4).

In terms of demographic covariates predicting cognitive functioning in models examining both birth weight and gestational age, the paths predicting cognitive functioning from sex were significantly different from zero in all four models (estimates ranged between .087 to .088), indicating that female participants had significantly higher cognitive functioning than males. The paths predicting cognitive functioning from race were not significantly different from zero (estimates at .025 to .026), indicating that being white was no longer associated with cognitive outcomes adjusting for natal variables. Similarly, the paths predicting cognitive functioning from mother's prenatal socio-economic status were not significantly different from zero (estimated at -.008 to -.002). However, paths predicting cognitive functioning from prenatal maternal education were significantly different from zero (estimates from .098 to .100), such that higher maternal education was consistently related to better cognitive outcomes in offspring.

In all models, each indirect path between an assessment of cognitive functioning and the previous assessment were significant, with path estimates ranging from .41-.90, all $p < .001$.

Extensions of the Model: Second-order Stability Paths

To account for the longer-term stability of cognitive functioning, the third model comparison specifies paths linking each assessment of cognitive functioning, not only to the previous assessment, but also to the assessment prior to that. For example, the sixth assessment of cognitive functioning (Grade 3 PIAT) is predicted not only by the fifth assessment (Grade 2 PIAT), but also by the fourth assessment (Grade 1 PIAT).

Predicting cognitive functioning from birth weight, both models exhibited good absolute model fit. The Enduring Effects model with second order stability paths (RMSEA = .012-.058, CFI = .989) is not significantly different than the Revisionist model with stability paths (RMSEA 90% CI = .011-.057, CFI = .989), $\Delta\chi2 = .96$, $p = .33$. The direct path between birth weight and the first assessment (*a* path) was estimated at .20, $p = .003$ and direct paths in the Enduring Effects model between birth weight and later assessments (the *b* paths) were estimated at .012, $p = .33$ (see Table 3 and Figure 5).

Predicting cognitive functioning from gestational age, the Enduring Effects model with second order stability paths (RMSEA = .017-.060, CFI = .988) is not significantly different than the Revisionist model with stability paths (RMSEA 90% CI = .018-.060, CFI = .987), $\Delta\chi2 = 1.83$, $p = .18$. The direct path between gestational age and the first assessment (*a* path) was estimated at .11, $p = .11$ and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.016, $p = .18$ (see Table 4 and Figure 6).

In all models predicting cognitive functioning with second-order stability paths, seven of ten stability paths significantly predicted later cognitive functioning.

Extensions of the Model: Covariates and Stability Paths

Finally, in the most complex model, cognitive functioning is predicted with both demographic covariates and second order stability paths. These models provide the most rigorous test of the Enduring Effects model in that they account for powerful demographic risk factors that co-vary with birth weight and control for the effect of earlier cognitive functioning on later cognitive functioning.

Predicting cognitive functioning from birth weight, the Enduring Effects model with second order stability paths and demographic covariates (RMSEA = .042-.068, CFI = .961) is not significantly different than the corresponding Revisionist model with stability paths and demographic covariates (RMSEA 90% CI = .042-.068, CFI = .960), $\Delta\chi 2 = 2.08$, $p = .15$. Both models demonstrated good model fit. Consistent with previous models, the direct path between birth weight and the first assessment (*a* path) was estimated at .20, $p = .003$. Direct paths in the Enduring Effects model between birth weight and later assessments (the *b* paths) were estimated at .018, $p = .15$ (see Table 3 and Figure 7).

Predicting cognitive functioning from gestational age when accounting for stability paths and covariates, both models exhibited good fit. The Enduring Effects model with second order stability paths and demographic covariates (RMSEA = .042-.067, CFI = .960) is not significantly different than the Revisionist model with stability paths and demographic covariates (RMSEA 90% CI = .042-.068, CFI = .960), $\Delta\chi 2 = 1.21$, $p = .27$. The direct path between gestational age and the first assessment (*a* path) was estimated at .11, $p = .10$, and direct paths in the Enduring Effects model between gestational age and later assessments (the *b* paths) were estimated at -.013, $p = .27$ (see Table 4 and Figure 8).

Like the covariate-only extensions, the paths estimating sex and maternal education significantly predicted cognitive functioning, whereas race and maternal socioeconomic status did not. As before, female sex and higher maternal education each independently predicted slightly higher cognitive functioning (estimates = .07 for sex; 07 to .08 for maternal education).

Basic Comparisons Between Enduring Effects and Revisionist models of Birth Weight/Gestational Age Predicting Social Competence

Although the early associations between birth weight and gestational age with social competence were quite weak, I conducted model comparisons as an educational exercise.

In the basic birth weight model predicting social competence, there is no statistically significant difference between the basic Enduring Effects model (RMSEA 90% CI = .082-.125, CFI = .758) and the basic Revisionist model (RMSEA 90% CI = .080-.122, CFI = .759), $\Delta\chi2$ = .64, p = .42, favoring the Revisionist Effects model. Both models exhibited poor absolute fit. The direct path between birth weight and the first assessment (*a* path) was estimated at .007, p = .93, and direct paths between birth weight and later assessments (the *b* paths) were estimated at -.021, p = .42 (see Table 5 and Figure 9). Thus, consistent with bivariate findings, birth weight was not related to social functioning either in infancy or later in development.

Using gestational age model to predict social functioning, but the Enduring Effects and Revisionist Effects models fit poorly. There is no statistically significant difference between the basic Enduring Effects model (RMSEA 90% CI = .082 -.125, CFI = .758) and the basic Revisionist model (RMSEA 90% CI = .080-.122, CFI = .760), $\Delta\chi2$

= 0.41, *p* = .52. Consistent with birth weight models and bivariate correlations, gestational age was not significantly related to social functioning at any time point: the direct path between gestational age and the first assessment (*a* path) was estimated at -.10, *p* = .19 and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.02, *p* = .56 (see Table 6 and Figure 10).

Extensions of the Model: Covariates

Predicting social competence from birth weight, the Enduring Effects model with demographic covariates (RMSEA = .052-.084, CFI = .804) and Revisionist Effects model with demographic covariates (RMSEA 90% CI = .051-.083, CFI = .804) demonstrated good-to-mediocre model fit. There was not significant differences between the two models, $\Delta\chi 2$ = .78, *p* = .38. This favors the less complex Revisionist Effects model. The direct path between birth weight and the first assessment (*a* path) was estimated at .007, *p* = .92 and direct paths between birth weight and later assessments (the *b* paths) were estimated at -.02, *p* = .38 (see Table 5 and Figure 11).

Predicting social competence from gestational age, there was no statistically significant difference between the Enduring Effects model with demographic covariates (RMSEA = .041-.079, CFI = .840) and the Revisionist model with demographic covariates (RMSEA 90% CI = .040-.078, CFI = .843), $\Delta\chi 2$ = .32, *p* = .57. Both models exhibited good-to-mediocre fit. The direct path between gestational age and the first assessment (*a* path) was estimated at -.10, *p* = .18 and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.02, *p* = .57 (see Table 6 and Figure 12).

In terms of demographic covariates, the estimates for sex predicting social competence were significantly different from zero in all four models (estimated at .20), indicating a consistent small-to-medium association between female sex and higher social competence. The paths predicting social competence from race were not significantly different from zero (estimated at .08), indicating that white and non-white participants did not significantly differ in social competence adjusting for natal variables. Consistent with findings from cognitive models, the paths predicting social competence from mother's prenatal socio-economic status were not significantly from zero (estimated at .05), but prenatal maternal education significantly predicted higher social competence through early adulthood (estimated from .11).

In all models, each indirect path between an assessment of social competence and the previous assessment were significant, with path estimates ranging from .15-.49, all $p < .05$. This indicates modest to moderately strong stability in social competence across development.

Extensions of the Model: Second-order Stability Paths

Predicting social competence from birth weight, the Enduring Effects model with second-order stability paths (RMSEA = .027-.085, CFI = .942) is not significantly different than the Revisionist model with stability paths (RMSEA 90% CI = .025-.082, CFI = .944), $\Delta\chi 2 = .63$, $p = .43$, with both models exhibiting good absolute fit. The direct path between birth weight and the first assessment (*a* path) was estimated at .00, $p = .99$ and direct paths in the Enduring Effects model between birth weight and later assessments (the *b* paths) were estimated at -.02, $p = .43$ (see Table 5 and Figure 13).

Predicting social competence from gestational age accounting for second order stability paths, both models fit well. The Enduring Effects model with second-order stability paths (RMSEA = .028-.085, CFI = .942) is not significantly different than the Revisionist model with stability paths (RMSEA 90% CI = .025-.082, CFI = .945), $\Delta\chi 2$ = .12, p = .73. The direct path between gestational age and the first assessment (*a* path) was estimated at -.11, p = .13 and direct paths between gestational age and later assessments (the *b* paths) were estimated at -.008, p = .73 (see Table 6 and Figure 14).

In all models, five of six stability paths significantly predicted later social functioning, indicating moderate stability over time in social competence.. The only non-significant second-order path was between age 16 social competence and age 32 social competence.

Extensions of the Model: Covariates and Stability Paths

Predicting social competence from birth weight, the Enduring Effects model with second-order stability paths and demographic covariates (RMSEA = .012-.059, CFI = .942) is not significantly different than the Revisionist model with stability paths (RMSEA 90% CI = .011-.058, CFI = .943), $\Delta\chi 2$ = .76, p = .38. Both models exhibited good absolute fit. The direct path between birth weight and the first assessment (*a* path) was estimated at .002, p = .98, and direct paths in the Enduring Effects model between birth weight and later assessments (the *b* paths) were estimated at -.02, p = .38 (see Table 5 and Figure 15).

Predicting social competence from gestational age, the Enduring Effects model with second order stability paths and demographic covariates (RMSEA = .010-.059, CFI = .945) and the Revisionist Effects model with stability paths and demographic covariates (RMSEA 90% CI = .006-.057, CFI = .947) demonstrated excellent-to-good absolute fit. There was no significant differences between the two models, $\Delta\chi2 = .06$, $p = .80$. The direct path between gestational age and the first assessment (*a* path) was estimated at -.11, $p = .14$, and direct paths in the Enduring Effects model between gestational age and later assessments (the *b* paths) were estimated at -.006, $p = .80$ (see Table 6 and Figure 16).

Like the covariate-only extensions, the paths estimating sex and maternal education significantly predicted cognitive functioning such that women and participants with more educated mothers demonstrated higher social competence., Race and maternal socioeconomic status did not predict social competence. Consistent with the stability path-only models, five of six second-order paths significantly predicted later social competence.

Post-Hoc Tests: Predicting Cognitive Functioning from Birth Weight using Gestational Age as a Control

After finding consistent bivariate associations between only cognitive functioning and birth weight, I conducted a post-hoc set of regressions and model comparisons using birth weight as the focal predictor and gestational age as a control to predict cognitive functioning. Regressing each assessment of cognitive functioning on birth weight and gestational age, birth weight significantly predicted cognitive functioning at ten of twelve assessments (all $\beta > .17$, all $p < .07$) and gestational age significantly predicted cognitive functioning at four of twelve assessments (β between -.19 and .01 and p between .001 and .90).

For post hoc model comparisons, the path between birth weight and the first assessment is allowed to vary in both the Enduring Effects models and Revisionist Effects models. In the Enduring Effects models, the other indirect *(b)* paths are allowed to differ from zero but are forced to be the same at each assessment. In the Revisionist Effects models, the indirect *(b)* paths are forced to be zero. In all four model comparisons, gestational age is treated as a covariate. Thus, the path from gestational age is allow to differ from zero but is forced to be equal at all assessments, consistent with an enduring effect. In all models using gestational age as a covariate, the covariance path between birth weight and gestational age was estimated at .52.

In the basic model with only birth weight, gestational age, and the direct path from the previous assessment as predictors, the Enduring Effects model (RMSEA = .056-.084, CFI = .949) was a significantly better fit than the Revisionist Effects model (RMSEA 90% CI = .058-.085, CFI = .946), $\Delta\chi 2 = 6.69$, $p = .01$. The direct path between birth weight and the first assessment of cognitive functioning (*a* path) was estimated at .21, $p = .002$ and direct paths in the Enduring Effects model between birth weight and later assessments of cognitive functioning (the *b* paths) were estimated at .039, $p = .01$ (see Table 7 and Figure 17).

In the model with demographic and gestational age covariates, the Enduring Effects model (RMSEA = .055-.077, CFI = .931) was a significantly better fit than the Revisionist Effects model (RMSEA 90% CI = .057-.078, CFI = .927), $\Delta\chi 2 = 8.71$, $p = .003$. The direct path between birth weight and the first assessment of cognitive functioning (*a* path) was estimated at .22, $p = .001$ and direct paths in the Enduring

Effects model between birth weight and later assessments of cognitive functioning (the *b* paths) were estimated at .045, $p = .03$ (see Figure 18).

In the model with second order stability paths and gestational age as a covariate, the Enduring Effects model (RMSEA = .000-.052, CFI = .991) was a significantly better fit than the Revisionist Effects model (RMSEA 90% CI = .007-.053, CFI = .985), $\Delta\chi 2$ = 4.03, $p = .04$. The direct path between birth weight and the first assessment of cognitive functioning (*a* path) was estimated at .22, $p = .002$ and direct paths in the Enduring Effects model between birth weight and later assessments of cognitive functioning (the *b* paths) were estimated at .03, $p = .045$ (see Figure 19).

In the model with second-order stability paths and demographic as well as gestational age covariates, the Enduring Effects model (RMSEA = .038-.064, CFI = .962) was a significantly better fit than the Revisionist Effects model (RMSEA 90% CI = .040-.065, CFI = .960), $\Delta\chi 2$ = 5.65, $p = .01$. The direct path between birth weight and the first assessment of cognitive functioning (*a* path) was estimated at .22, $p = .001$ and direct paths in the Enduring Effects model between birth weight and later assessments of cognitive functioning (the *b* paths) were estimated at .036, $p = .02$ (see Figure 20).

Discussion

Using data from the Minnesota Longitudinal Study of Risk and Adaptation (Sroufe et al., 2005), I examined whether there were associations linking birth weight and gestational age with cognitive and social functioning. I also investigated whether those associations were better explained by an enduring or a revisionist framework. Bivariate correlations indicated that birth weight was positively associated with cognitive functioning across childhood and adolescence, whereas birth weight was not associated with social functioning. Gestational age was not associated with either cognitive or social functioning. These preliminary findings supported further investigation of the pattern of associations between birth weight and cognitive functioning using enduring effects versus revisionist effects models of development.

In an absolute sense, the most basic models had poor fit, with the upper bounds of the RMSEA confidence intervals above .12 for social competence and above .09 for cognitive functioning. Including stability paths and demographic covariates improved absolute model fit. For cognitive functioning, the best fitting models featured only stability paths, whereas the models with demographic covariates and stability paths performed best with regards to social competence.

Cognitive Functioning

Hypothesis 1 was partially supported, in that there were significant, positive associations between birth weight and cognitive functioning at age 24 months; however, contrary to predictions, there were no significant associations between gestational age and cognitive functioning at 24 months.

The bivariate associations between birth and cognitive functioning match the direction and magnitude of previous examinations of normative birth weight infants and cognitive functioning reviewed by Shenkin et al. (2004). While one might have concluded that consistent correlations would result in Enduring Effects, this study has provided novel insight into the nature of these associations. In fact, the revisionist effects model fit the data better than the enduring effects model. In three of the four comparisons made, only one (basic model with demographic covariates) favored the enduring effects model. The indirect paths between birth weight and cognitive functioning were estimated between .02 and .03 (in standardized coefficients). This result does not support *Hypothesis 2*, as I predicted that birth weight and gestational age would predict cognitive functioning and that associations between those predictors and cognitive functioning would endure over time.

Descriptively, associations between birth weight and cognitive functioning began to decrease after adolescence, dropping from r = .20 to .06 between age 16 and age 23. These associations then remain somewhat stable, remaining at approximately .10 between age 26 and 34. There are two plausible explanations for this drop in associations. One is that development changes qualitatively between adolescence and young adulthood and, thus, cognitive functioning at age 24 may be affected by different factors than at age 16 years. Just as educational attainment is distinct from cognitive ability and academic achievement, young adulthood is distinct from adolescence (Arnett, 2000). Thus, the effects of birth weight could diminish for substantive reasons, such as the slowing of brain development (Chourchesne et al., 2000; Giedd et al., 1999).

Another possibility is that heterogeneity in measurement of cognitive functioning could impact this association. Cognitive functioning was directly assessed via standardized achievement or aptitude tests from age 24 months to 16 years, but at age 24 years it was assessed via educational attainment. Educational attainment (particularly as it relates to college enrollment) may be more impacted by social and demographic variables than the ability and achievement tests used during the childhood and adolescent assessments. For example, years of education may be shaped by cultural and familial norms around attending college, desired career (which may require more or less formal education), and multiply determined life events (e.g., illness, childbirth) in addition to raw cognitive ability.

Consistent with the current findings, research using the Chicago Longitudinal Study found that low birth weight did not impact educational attainment at age 20 (Ou & Reynolds, 2008). Among individual-level factors, self-reported academic competence was the strongest predictor, but was outweighed by demographic factors such as race, gender, maternal education and free lunch status. This mirrors findings from my analyses showing moderate bivariate associations between educational attainment in adulthood and higher maternal education and maternal socio-economic status, but null associations with birth weight. Furthermore, the current findings indicate that demographic factors were equally predictive of cognitive functioning when assessed directly using standardized measures at age 24 months through 16 years.

This shift in assessment can be seen in the disparity in strength of stability paths before and after the measurement strategy changes. The direct path between the last standardized assessment of cognitive functioning (age 16 Woodcock-Johnson) and the first assessment of educational attainment (age 23) is estimated at .37, in contrast to all other direct paths before and after this shift (estimated between .57 and .86).

This discrepancy raises the possibility that the pattern of associations may change when measurement strategy shifts. However, a post hoc analysis using more homogenous measures (i.e., standardized aptitude and achievement tests) through a shorter assessment period (i.e., 24 months to 16 years) still favors a revisionist perspective. Predicting cognitive functioning from birth weight to age 16 years rather than age 34 years did not change the results of significance tests of any of the four model comparisons. Truncating the age range resulted in non-significant increases in the strength of estimated direct paths from birth weight to later cognitive functioning (e.g., from .018, $p = .15$, to .027, $p = .09$ in the most complex model containing stability paths and demographic controls. This post-hoc finding provides stronger support for the Revisionist Effects model, and emphasizes the need for longitudinal analysis. Every single bivariate associations between birth weight and cognitive functioning to age 16 years is statistically significant, each of which considered in a cross-sectional analysis might lead to a researcher to conclude that birth weight continues to impact cognition in adulthood. However, when considered in the context of a participants' early cognitive functioning, even associations of consistent magnitude across fourteen years can fit a Revisionist Effects framework.

More importantly, the direct associations between each assessment of cognitive functioning are much stronger than the direct path, ranging from .40-.90 in the basic model. Thus, children who show higher cognitive functioning at one age are very likely to continue performing well. Although birth weight is directly associated with early cognitive functioning (estimated at .20 at age 24 months), later cognitive functioning is much more strongly associated with earlier cognitive functioning compared to natal variables.

Overall, results indicated that birth weight, at least in the MLSRA, is *not* independently and directly associated with cognitive functioning across the lifespan. Instead, associations attenuate over time, such that differences in cognitive functioning in middle childhood, adolescence, and early adulthood are primarily a function of variation in cognitive functioning earlier in life.

The bivariate associations match the direction and magnitude of previous examinations of normative birth weight infants and cognitive functioning reviewed by Shenkin et al. (2004). While one might have concluded that consistent correlations would result in Enduring Effects, this study has provided novel insight into the nature of these associations. Birth weight, at least in the MLSRA, is *not* independently and directly associated with cognitive functioning across the lifespan. Instead, associations attenuate over time and differences in cognitive functioning in middle childhood, adolescence, and early adulthood are primarily a function of variation in cognitive functioning earlier in life.

Social Functioning

Hypothesis 3 was not supported, in that there were no significant associations between birth weight or gestational age and social competence in kindergarten. Furthermore, at no assessment did birth weight or gestational age predict social competence. This is a novel finding, given the lack of extant literature studying birth weight and social competence within the normative birth weight range. When finding null effects, however, there is always the possibility of the file drawer problem: prior researchers may have tested for associations between natal variables and social competence but not pursued publication due to lack of significant effects. There is ample evidence that LBW/EGA infants have poorer social competence through middle childhood than NBW/NGA infants, as reported by parents, teachers, and the children themselves (Farooqi et al., 2007; Hoy et al., 1992; Indredavik et al., 2005; McCormick et al., 1996; Nadeau et al., 2011; Rickards, Kelly, Doyle & Callanan, 2001; Ross et al., 1990). However, the current findings suggest that social functioning is not significantly related to variations in birth weight and gestational age within the normative range.

Although I did not expect enduring associations between birth weight/gestational age and social competence, I predicted that there would be early associations between birth weight/gestational age and social competence. In contrast to these hypotheses, neither birth weight nor gestational age predicted peer competence in kindergarten. Of note, the earliest assessments of social competence occurred at least three years later than the earliest assessments of cognitive functioning, so it could be that assessing social competence as early as age 24 months may have demonstrated a revisionist pattern. However, given the available data, it appears that social functioning is not associated with birth weight and gestational age. This information is novel in that these associations have not yet been tested in long-term longitudinal studies, and findings are of practical use to parents and clinicians weighing the consequences of birth timing.

Cognitive Functioning: Why Not Gestational Age?

Although there were consistent associations between birth weight and cognitive functioning until age 16 years, there were no significant associations between gestational age and cognitive functioning at any time point. However, this finding is contrary to findings from Ekeus et al. (2010), who found differences in cognitive functioning as a function of gestational age among lower SES men at age 19.

There also is meta-analytic evidence for differences between pre-term and term infants in cognitive functioning (Kerr-Wilson et al., 2011). Among infants born pre-term, there was a linear relation of gestational age by week and later cognitive functioning. The authors did not investigate differences within children born at term, so it could simply be that variation within this spectrum does not reliably predict cognitive functioning. This is especially demonstrated in the MLSRA by the weak initial association between gestational age and cognitive functioning.

Yang et al. (2011) found a parabolic relation between gestational age within the normative range and cognitive ability at age 6.5, wherein children born at 40 weeks showed the highest scores on the Wechsler Abbreviated Scales of Intelligence. This curvilinear association could have accounted for the low correlations between gestational age and cognitive functioning in the MLSRA. However, post-hoc analyses in the current data set confirmed that the quadratic gestational age term was not significant at any of the assessments, with p from .06 to .97.

The differential effect of birth weight and gestational age is an unexpected result. Previous research had shown that children born EGA tend to have diminished cognitive functioning at a variety of ages, and that variation in normative gestational age is associated with cognitive functioning. However, there are differences between this study and Yang et al.'s (2011) research. Yang and colleagues' study was conducted with a normative risk sample in Belarus with participants born 20 years after the MLSRA cohort. These differences in developmental context could account for differences in the nature of associations between gestational age and cognitive functioning. However, confidence in the current contrasting results must factor in that Yang et al.'s (2011) analysis had a much larger sample size (n = 13,824 compared to 267). Future research investigating the potential enduring effects of birth weight and gestational age should explore this difference, which might allow for prioritization of birth weight over gestational age for researchers and practitioners.

Birth Weight Controlling for Gestational Age

In contrast to primary findings, post hoc analyses predicting cognitive functioning when controlling for gestational age revealed that a small effect of birth weight that consistently endured over time. I conducted these analyses after observing bivariate associations between only birth weight and cognitive functioning, in order to further isolate the effect of birth weight above and beyond other predictors. This effect was significant in all four models when controlling for demographic covariates, second order stability paths, and both in the same model. The estimates of the Enduring Effects paths ranged in magnitude between .030-.045. If cognitive functioning were conceptualized in terms of IQ, an increase of one standard deviation in birth weight (approximately 540 grams) controlling for gestational age would correspond with approximately half an IQ point.

I do not believe that either birth weight alone or birth weight when controlling for gestational age is a "better" test of birth weight's predictive significance, but rather that both tests provide useful information about the legacy of early experience. Low birth weight captures information about the prenatal environment that may include factors precipitating early birth. In contrast, birth weight controlling for gestational age isolates factors associated with body size independent of the duration of fetal development. These factors have been studied in prior research on children born small for gestational age (SGA).

Much like research comparing children born LBW to children born NBW children, research on children born SGA often involves categorical comparisons. Often, these studies compare children based on a cutoff (for instance, lower than 5th percentile for gestational age) to a matched control group. In samples of children born pre-term, cognitive functioning deficits among children born SGA were found at age 6 years (McCarton, Wallace, Divon & Vaughn, 1996) and age 9 years (Hutton, Pharoah, Cooke & Stevenson, 1997). In samples of infants born at term (after 37 weeks), there is evidence of reduced cognitive functioning for children born SGA at age 5 years (Sommerfeldt et al., 2000; Strauss, 2000), age 12 years, age 18 years (Larroque, Bertrais, Czernichow & Leger, 2001; Strauss, 2000), and age 26 years (Strauss, 2000). De Bie, Oostrom and Delemarre-can de Waal (2010) review studies examining children born SGA at term and found decreased cognitive functioning compared to matched controls in eight of eleven studies. I am not aware of any other study that investigates continuous variations in size (i.e., birth weight) for gestational age as a predictor of developmental outcomes.

In the MLSRA, enduring associations between cognitive functioning and birth weight controlling for gestational age are small but significant. These enduring effects hold when accounting for demographic differences and stability in cognitive functioning over time. However, it is important to note that the effect size associated with birth weight controlling for gestational age is relatively smaller than that of maternal education, sex, and the previous assessment of cognitive functioning. This result should be interpreted with caution, as the magnitude of the enduring effect paths are not vastly different from the enduring effects paths when only birth weight is in the model (See Figure 3) but cross the threshold for statistical significance. This, when combined with their post-hoc nature, underscores the need for replication before serious consideration is made.

Comparison to Other Tests of the Enduring Effects Model

Other tests of the Enduring Effects vs. Revisionist Models have started with stronger associations between the focal predictors and outcomes that did not diminish over time. As such, they have often demonstrated Enduring Rather than Revisionist Effects. In addition, previous tests of the Enduring Effects model may have stronger theoretical explanations for the mechanisms of the paths from earlier experience to later outcomes. Three prior studies found enduring effects of maternal sensitivity for academic competence, social competence, and psychopathology (Fraley et al., 2013; Haltigan et al., 2013; Raby et al., 2015); these studies were grounded in attachment theory, which proposes that internal working models based on early experience persist across development. Similarly, enduring deleterious effects of childhood abuse and neglect may reflect expected disruptions in children's navigation of stage-salient developmental tasks, consistent with an organizational perspective on development (Raby et al., in press). Theorized mediators between early caregiving experience and later functioning are somewhat more explicit and may be longer-lasting than the mechanisms that presumably link birth weight and cognitive functioning.

Lessons for Intervention

Given the null effects for birth weight and gestational age predicting social functioning, interventions would be better served targeting other precursors to reduced social competence. In terms of birth weight predicting cognitive functioning, the revisionist effects model best fits the data, meaning that interventions focused on the effects of birth weight should be conducted early, as later cognitive performance is primarily a function of previous cognitive performance. Orton, Spittle, Doyle, Anderson and Boyde (2009) reviewed interventions for infants born pre-term and below normal birth weight. Among studies intervening before three years of age, the total effect was estimated d = .42. This estimate was larger than that of interventions that took place between 5 and 13 years of age, but similar to the estimate of interventions that took place between age 3 years and 5 years. Intervening prior to school age may help children with lower birth weight to catch up with their peers and optimize their cognitive readiness for learning. Interventions after infancy should focus on impacting cognitive functioning via non-birth weight/gestational age mechanisms, as the effects of these variables do not endure across development.

In terms of children born small for gestational age, an Enduring Effects model best fits the data. This means that interventions designed to reduce the negative effects of lower birth weight for gestational age may continue to be effective later in childhood. For children who are very low in birth weight for their gestational age (less than two standard deviations below the median), an important predictor of normal intellectual performance was whether infants born small for gestational age had “caught up” to normal height and weight by age 18 years (Lundgren, Cnattingius, Jonsson & Tumevo, 2001). Thus, an effective intervention may focus more on physical health, adequate nutrition, and physiological development rather than targeting psychological processes.

Strengths and Limitations of This Study

First, this study benefits from its prospective, longitudinal design, which allows for the examination of developmental trajectories over time. The multi-method assessment of stage-salient developmental tasks across this time is also a strength. Finally, this study benefits from a rigorous model comparison framework.

In addition to notable strengths, this study has a few limitations. First, this study design is entirely correlational. Even where significant associations exist, it is unclear whether they are causal in nature. This is likely to continue in birth weight and gestational age research, given that it is unethical to attempt to experimentally manipulate when a person is born or how much they weigh. Although statistically controls for demographic factors and second-order stability improve causal inference, causal direction cannot be firmly established in the absence of randomized controlled trials.

Second, I cannot eliminate genetic differences as a possible third variable linking birth weight to cognitive functioning. Birth weight (Lunde et al., 2007; Magnus et al., 1984), intelligence (Plomin & Dreary, 2015; Plomin & von Stumm, 2018), and educational achievement (Krahpol et al., 2014) are all highly heritable. Thus, it could be that some genotypic variation may be responsible for the phenotypic variation across all these domains, or that environmental precursors of birth weight may be one of many gene-by-environment interactions that determine a person's cognitive functioning (Sauce & Matzel, 2018). Genetically informed longitudinal studies are required to rule out this potential confound.

The assessment of both cognitive functioning and social competence also has limits. Cognitive functioning was assessed via aptitude tests, achievement tests, and educational attainment. All of these approximate general cognitive functioning, but none are perfect operationalizations. Additionally, lack of consistency in measurement may have resulted in unstable estimations, in that birth weight and gestational age may more strongly predict one method than another. For example, social competence was measured via teacher report and observer report of adult romantic competence from interviews. Although developmentally appropriate, these are very different approximations of social functioning that assess very different domains of social life. Additionally, each assessment method has its own limitations. Regarding teacher reports of classroom peer functioning, school is only one social setting, and teachings are only one judge within that setting. Other reporters might have reduced error and provided a fuller accounting of participants' social competence. An interview about romantic history and functioning also privileges what a participant was willing and able to disclose, and lacks the ecological validity of a rater who observed the participant in everyday life. In addition to these limitations in measurement, this study also conducted 16 model comparisons that were specified a priori and 4 additional exploratory model comparisons. The study-wise error rate is inflated by this multitude of tests, and caution should be used when interpreting significant differences between models, especially given the small effect sizes.

The model comparison framework used here also allows the exact mechanisms of associations between birth weight and cognitive functioning to remain opaque. Although previous research suggests that reduced neurological development may mediate the relation between birth weight and cognitive functioning (with or without controls for gestational age), the MLSRA did not measure brain development. These processes may not function identically for birth weight within the normative range and further research is needed on potential neurological mediators of cognitive effects.

Finally, the comparison of enduring effects vs. revisionist effects models also precludes the analysis of moderating variables. For instance, I did not test whether there are stronger effects of birth weight and gestational age on cognitive and social outcomes when children are born in low SES environments compared to relatively higher SES environments. I also did not test demographic moderators such as gender, which have previously been shown to affect the strength of associations between VLBW and intelligence (Hack et al., 2004).

Next Directions and Conclusions

Future research should expand this investigation in higher-powered, normative risk samples. This study is somewhat underpowered and the reliability of estimated paths could be increased with a larger sample size. It could be that for participants who began their lives in poverty, factors outside of birth weight and gestational age could have a comparatively greater impact. Of note, however, this is contrary to predictions I would have made a priori. Future research should also investigate the specific mechanisms underlying the initial associations between birth weight and cognitive functioning at 24 months. These mechanisms, likely neurological in nature, may be key in designing successful early interventions.

Finally, future research should examine, with strong a priori hypotheses, the effect of birth weight for gestational age on cognitive functioning. Within the normative range of both gestational age and birth weight, the unique effect of size for gestational ag appears to have enduring significance for later cognitive functioning. Given the exploratory nature of these analyses, I am wary of overconfidence in their results.

Although the effect sizes are small, continued work is needed to better understand why birth weight, controlling for the effect of gestational age, impairs cognitive development.

Overall, this study used a novel framework to investigate birth weight and gestational age within the normative range predicting cognitive functioning and social competence. Neither birth weight nor gestational age predicted social functioning. These questions have largely gone unanswered and the answers provided herein supply new information about birth characteristics within the normative range and their impact on later social functioning.

In keeping with previous studies, there were significant bivariate associations between birth weight and cognitive functioning from age 24 months until age 16 years. However, in contrast to previous work (e.g. Ekeus et al., 2010; Kerr-Wilson et al. 2011), there were no bivariate associations between gestational age and cognitive functioning. The Revisionist Effects Model best explained the associations between birth weight and cognitive functioning, in that direct associations did not endure throughout the course of the study. These findings provide new information about the long-term relations between birth weight and cognitive functioning, and suggest that parents of lower birth weight infants should try to make up deficits in cognitive functioning within the first two years of life if possible.

Finally, post-hoc exploratory tests found enduring but small effects of birth weight on cognitive functioning through age 34 years when controlling for gestational age. This result held when accounting for demographic characteristics of the mother and child, as well as stability within the outcome domain. These finding should be retested in a confirmatory framework to increase inferential confidence.

The new information provided by this study adds to psychologists' understanding of the processes underlying previously reported associations between birth weight and cognitive functioning, and suggests that variation within the normal range of birth weight and gestational age does not significantly predict social functioning. This null association is encouraging, as it indicates that normative variations in these natal variables do not confer social risk. The revisionist nature of birth weight effects is also promising, as it suggests that intensive intervention may not be required to help infants to catch up cognitively with peers. Even among lower birth weight infants with early cognitive deficits, early intervention may be reasonable expected to avert long-term decrements in cognitive functioning. Finally, although birth weight was enduring effects on cognitive functioning when controlling for gestational age, the effect size was extremely small.

This study thus offers valuable new information regarding the magnitude and patterning of cognitive risks associated with birth weight (but not gestational age) within the normative range of development. Furthermore, it suggests that normative variations in natal variables are not associated with significant social risk. Results represent an important step in better understanding the boundary conditions of developmental risks associated with birth weight and gestational age, with potential implications for medical decision-making and targeted intervention.

References

Aarnoudse-Moens, C. S. H., Weisglas-Kuperus, N., van Goudoever, J. B., & Oosterlaan, J. (2009). Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*, *124*, 717-728.

Anderson, P., Doyle, L. W., & Victorian Infant Collaborative Study Group. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *Journal of the American Medical Association*, *289*, 3264-3272.

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, 55, 469-480.

Bakeman, R., & Brown, J. V. (1980). Early interaction: Consequences for social and mental development at three years. *Child Development*, 437-447.

Bayley, N. (1969). *Manual for the Bayley scales of infant development*. Psychological Corporation.

Bayley, N. (1993). *Bayley scales of infant development: Manual*. Psychological Corporation.

Bhutta, A. T., Cleves, M. A., Casey, P. H., Cradock, M. M., & Anand, K. J. S. (2002). Cognitive and behavioral outcomes of school-aged children who were born preterm: a meta-analysis. *Journal of the American Medical Association*, *288*, 728-737.

Boardman, J. D., Powers, D. A., Padilla, Y. C., & Hummer, R. A. (2002). Low birth weight, social factors, and developmental outcomes among children in the United States. *Demography*, *39*, 353-368.

Boyle, M. H., Miskovic, V., Van Lieshout, R., Duncan, L., Schmidt, L. A., Hoult, L., ... & Saigal, S. (2011). Psychopathology in young adults born at extremely low birth weight. *Psychological Medicine*, *41*, 1763-1774.

Breslau, N., Brown, G. G., DelDotto, J. E., Kumar, S., Ezhuthachan, S., Andreski, P., & Hufnagle, K. G. (1996). Psychiatric sequelae of low birth weight at 6 years of age. *Journal of Abnormal Child Psychology*, *24*, 385-400.

Bussières, E. L., Tarabulsy, G. M., Pearson, J., Tessier, R., Forest, J. C., & Giguère, Y. (2015). Maternal prenatal stress and infant birth weight and gestational age: A meta-analysis of prospective studies. *Developmental Review, 36,* 179-199.

Clark, C. A., Woodward, L. J., Horwood, L. J., & Moor, S. (2008). Development of emotional and behavioral regulation in children born extremely preterm and very preterm: Biological and social influences. *Child Development*, *79*, 1444-1462.

Collins, W. A., & van Dulmen, M. (2006). The significance of middle childhood peer competence for work and relationships in early adulthood. *Developmental Contexts in Middle Childhood: Bridges to Adolescence and Adulthood*, 23-40.

Conrad, A. L., Richman, L., Lindgren, S., & Nopoulos, P. (2010). Biological and environmental predictors of behavioral sequelae in children born preterm. *Pediatrics*, *125*, 83-89.

Courchesne, E., Chisum, H. J., Townsend, J., Cowles, A., Covington, J., Egaas, B., ... & Press, G. A. (2000). Normal brain development and aging: quantitative analysis at in vivo MR imaging in healthy volunteers. *Radiology*, *216*, 672-682.

Crnic, K. A., Ragozin, A. S., Greenberg, M. T., Robinson, N. M., & Basham, R. B. (1983). Social interaction and developmental competence of preterm and full-term infants during the first year of life. *Child Development*, 1199-1210.

Cserjesi, R., Van Braeckel, K. N., Timmerman, M., Butcher, P. R., Kerstjens, J. M., Reijneveld, S. A., ... & Geuze, R. H. (2012). Patterns of functioning and predictive factors in children born moderately preterm or at term. *Developmental Medicine & Child Neurology*, *54*, 710-715.

de Kieviet, J. F., Zoetebier, L., Van Elburg, R. M., Vermeulen, R. J., & Oosterlaan, J. (2012). Brain development of very preterm and very low‐birthweight children in childhood and adolescence: a meta‐analysis. *Developmental Medicine & Child Neurology*, *54*, 313-323.

De Bie, H. M. A., Oostrom, K. J., & Delemarre-Van De Waal, H. A. (2010). Brain development, intelligence and cognitive outcome in children born small for gestational age. *Hormone Research in Paediatrics*, *73*, 6-14.

Delobel-Ayoub, M., Arnaud, C., White-Koning, M., Casper, C., Pierrat, V., Garel, M., ... & Kaminski, M. (2009). Behavioral problems and cognitive performance at 5 years of age after very preterm birth: the EPIPAGE Study. *Pediatrics*, *123*, 1485-1492.

Duncan, O. (1961). A socioeconomic index for all occupations. In A. J. Reiss, Jr. (Ed.), *Occupations and Social Status* (pp. 109–138). New York, NY: Free Press.

Dunn, L. M., & Markwardt, F. C. (1970). Peabody individual achievement test. American Guidance Service.

Ekeus, C., Lindström, K., Lindblad, F., Rasmussen, F., & Hjern, A. (2010). Preterm birth, social disadvantage, and cognitive competence in Swedish 18-to 19-year-old men. *Pediatrics, 125*, 67-73.

Englund, M. M., Egeland, B., Oliva, E. M., & Collins, W. A. (2008). Childhood and adolescent predictors of heavy drinking and alcohol use disorders in early adulthood: a longitudinal developmental analysis. *Addiction*, *103*, 23-35.

Fan, R. G., Portuguez, M. W., & Nunes, M. L. (2013). Cognition, behavior and social competence of preterm low birth weight children at school age. *Clinics*, *68*, 915-921.

Farooqi, A., Hägglöf, B., Sedin, G., Gothefors, L., & Serenius, F. (2007). Mental health and social competencies of 10-to 12-year-old children born at 23 to 25 weeks of gestation in the 1990s: A Swedish national prospective follow-up study. *Pediatrics*, *120*, 118-133.

Ford, M. E. (1982). Social cognition and social competence in adolescence. *Developmental Psychology*, *18*, 323.

Fraley, R. C., Roisman, G. I., & Haltigan, J. D. (2013). The legacy of early experiences in development: Formalizing alternative models of how early experiences are carried forward over time. *Developmental Psychology*, *49*, 109.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., ... & Rapoport, J. L. (1999). Brain development during childhood and adolescence: a longitudinal MRI study. *Nature Neuroscience, 2*, 861-863.

Gresham, F. M., & Elliott, S. N. (1990). *Social skills rating system: Manual.* American Guidance Service.

Hack, M., Klein, N. K., & Taylor, H. G. (1995). Long-term developmental outcomes of low birth weight infants. *The Future of Children*, 176-196.

Hack, M., Youngstrom, E. A., Cartar, L., Schluchter, M., Taylor, H. G., Flannery, D., ... & Borawski, E. (2004). Behavioral outcomes and evidence of psychopathology among very low birth weight infants at age 20 years. *Pediatrics*, *114*, 932-940.

Haltigan, J. D., Roisman, G. I., & Fraley, R. C. (2013). The predictive significance of early caregiving experiences for symptoms of psychopathology through midadolescence: Enduring or transient effects? *Development and Psychopathology*, *25*, 209-221.

Hooper, D., Coughlan, J., & Mullen, M. (2008). Evaluating model fit: a synthesis of the structural equation modeling literature. *7th European Conference On Research Methodology For Business and Management Studies*, 195-200.

Hoy, E. A., Sykes, D. H., Bill, J. M., Halliday, H. L., McClure, B. G., & Reid, M. C. (1992). The social competence of very-low-birthweight children: teacher, peer, and self-perceptions. *Journal of Abnormal Child Psychology*, *20*, 123-150.

Hutton, J. L., Pharoah, P. O., Cooke, R. W., & Stevenson, R. C. (1997). Differential effects of preterm birth and small gestational age on cognitive and motor development. *Archives of Disease in Childhood-Fetal and Neonatal Edition, 76*, 75-81.

Indredavik, M. S., Vik, T., Heyerdahl, S., Kulseng, S., & Brubakk, A. M. (2005). Psychiatric symptoms in low birth weight adolescents, assessed by screening questionnaires. *European Child & Adolescent Psychiatry*, *14*, 226-236.

Jaekel, J., Wolke, D., & Chernova, J. (2012). Mother and child behaviour in very preterm and term dyads at 6 and 8 years. *Developmental Medicine & Child Neurology*, *54*, 716-723.

Kagan, J. (1980). Four questions in psychological development. *International Journal of Behavioral Development*, *3*, 231-241.

Kenny, D. A. (2015). Measuring model fit. *Davidkenny.com*

Kerr-Wilson, C. O., Mackay, D. F., Smith, G. C. S., & Pell, J. P. (2011). Meta-analysis of the association between preterm delivery and intelligence. *Journal of Public Health*, *34*, 209-216.

Kogan, M. D. (1995). Social causes of low birth weight. *Journal of the Royal Society of Medicine*, *88*, 611-615.

Krapohl, E., Rimfeld, K., Shakeshaft, N. G., Trzaskowski, M., McMillan, A., Pingault, J. B., ... & Plomin, R. (2014). The high heritability of educational achievement reflects many genetically influenced traits, not just intelligence. *Proceedings of the National Academy of Sciences, 111*, 15273-15278.

Kramer, M. S. (1987). Determinants of low birth weight: methodological assessment and meta-analysis. *Bulletin of the World Health Organization*, *65*, 663.

Larroque, B., Bertrais, S., Czernichow, P., & Léger, J. (2001). School difficulties in 20-year-olds who were born small for gestational age at term in a regional cohort study. *Pediatrics, 108*, 111-115.

Lee, P. A., Chernausek, S. D., Hokken-Koelega, A. C., & Czernichow, P. (2003). International Small for Gestational Age Advisory Board consensus development conference statement: management of short children born small for gestational age, April 24–October 1, 2001. *Pediatrics, 111,* 1253-1261.

Lemerise, E. A., & Arsenio, W. F. (2000). An integrated model of emotion processes and cognition in social information processing. *Child Development*, *71*, 107-118.

Loe, I. M., Lee, E. S., Luna, B., & Feldman, H. M. (2011). Behavior problems of 9–16 year old preterm children: Biological, sociodemographic, and intellectual contributions. *Early Human Development*, *87*, 247-252.

Lunde, A., Melve, K. K., Gjessing, H. K., Skjærven, R., & Irgens, L. M. (2007). Genetic and environmental influences on birth weight, birth length, head circumference, and gestational age by use of population-based parent-offspring data. *American Journal of Epidemiology*, *165*, 734-741.

Lundgren, E. M., Cnattingius, S., Jonsson, B., & Tuvemo, T. (2001). Intellectual and psychological performance in males born small for gestational age with and without catch-up growth. *Pediatric Research, 50*, 91.

Magnus, P. (1984). Causes of variation in birth weight: a study of offspring of twins. *Clinical Genetics*, *25*, 15-24.

Magnus, P., Berg, K., Bjerkedal, T., & Nance, W. E. (1984). Parental determinants of birth weight. *Clinical Genetics*, *26*, 397-405.

Maupin, A. N., & Fine, J. G. (2014). Differential effects of parenting in preterm and full-term children on developmental outcomes. *Early Human Development*, *90*, 869-876.

McCarton, C. M., Wallace, I. F., Divon, M., & Vaughan, H. G. (1996). Cognitive and neurologic development of the premature, small for gestational age infant through age 6: Comparison by birth weight and gestational age. *Pediatrics, 98*, 1167-1178.

McCormick, M. C., Brooks-Gunn, J., Workman-Daniels, K., Turner, J., & Peckham, G. J. (1992). The health and developmental status of very low birth weight children at school age. *Journal of the American Medical Association*, *267*, 2204-2208.

Nadeau, L., Boivin, M., Tessier, R., Lefebvre, F., & Robaey, P. (2001). Mediators of behavioral problems in 7-year-old children born after 24 to 28 weeks of gestation. *Journal of Developmental & Behavioral Pediatrics*, *22*, 1-10.

Neisser, U., Boodoo, G., Bouchard Jr, T. J., Boykin, A. W., Brody, N., Ceci, S. J., ... & Urbina, S. (1996). Intelligence: Knowns and unknowns. *American Psychologist*, *51*, 77.

NICHD Early Child Care Research Network. (Eds.). (2005). *Child care and child development.* New York: Guilford Press.

Oken, E., Kleinman, K. P., Rich-Edwards, J., & Gillman, M. W. (2003). A nearly continuous measure of birth weight for gestational age using a United States national reference. *BMC Pediatrics*, *3*, 6.

Orton, J., Spittle, A., Doyle, L., Anderson, P., & Boyd, R. (2009). Do early intervention programmes improve cognitive and motor outcomes for preterm infants after discharge? A systematic review. *Developmental Medicine & Child Neurology, 51*, 851-859.

Ou, S. R., & Reynolds, A. J. (2008). Predictors of educational attainment in the Chicago Longitudinal Study. *School Psychology Quarterly*, *23*, 199.

Plomin, R., & Deary, I. J. (2015). Genetics and intelligence differences: Five special findings. *Molecular Psychiatry, 20*, 98-108.

Plomin, R., & von Stumm, S. (2018). The new genetics of intelligence. *Nature Reviews Genetics, 19*, 148-160.

Raby, K. L., Lawler, J. M., Shlafer, R. J., Hesemeyer, P. S., Collins, W. A., & Sroufe, L. A. (2015). The interpersonal antecedents of supportive parenting: A prospective, longitudinal study from infancy to adulthood. *Developmental Psychology*, *51*, 115.

Raby, K. L., Roisman, G. I., Fraley, R. C., & Simpson, J. A. (2015). The enduring predictive significance of early maternal sensitivity: Social and academic competence through age 32 years. Child Development, 86, 695-708.

Raby, K. L. , Roisman, G. I. , Labella, M.H., Martin, J. & Fraley, R. C. (In press) The legacy of early abuse and neglect for social and academic competence into adulthood. *Child Development.*

Raby, K. L., Roisman, G. I., Simpson, J. A., Collins, W. A., & Steele, R. D. (2015). Greater maternal insensitivity in childhood predicts greater electrodermal reactivity during conflict discussions with romantic partners in adulthood. *Psychological Science*, *26*, 348-353.

Rauh, V. A., Achenbach, T. M., Nurcombe, B., Howell, C. T., & Teti, D. M. (1988). Minimizing adverse effects of low birth weight: Four-year results of an early intervention program. *Child Development*, 544-553.

Razza, R. A., & Blair, C. (2009). Associations among false-belief understanding, executive function, and social competence: A longitudinal analysis. *Journal of Applied Developmental Psychology*, *30*, 332-343.

Richards, M., Hardy, R., Kuh, D., & Wadsworth, M. E. (2001). Birth weight and cognitive function in the British 1946 birth cohort: longitudinal population based study. *British Medical Journal*, *322*, 199-203.

Rickards, A. L., Kelly, E. A., Doyle, L. W., & Callanan, C. (2001). Cognition, academic progress, behavior and self-concept at 14 years of very low birth weight children. *Journal of Developmental & Behavioral Pediatrics*, *22*, 11-18.

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social–emotional competence. *Journal of Applied Developmental Psychology*, *27*, 300-309.

Risnes, K. R., Vatten, L. J., Baker, J. L., Jameson, K., Sovio, U., Kajantie, E., ... & Sundh, V. (2011). Birthweight and mortality in adulthood: a systematic review and meta-analysis. *International Journal of Epidemiology*, *40*, 647-661.

Roisman, G. I., & Fraley, R. C. (2013). Developmental mechanisms underlying the legacy of childhood experiences. *Child Development Perspectives*, *7*, 149-154.

Roisman, G. I., Susman, E., Barnett-Walker, K., Booth-LaForce, C., Owen, M. T., Belsky, J., ... & Steinberg, L. (2009). Early family and childcare antecedents of awakening cortisol levels in adolescence. *Child Development*, *80*, 907-920.

Ross, G., Lipper, E. G., & Auld, P. A. (1990). Social competence and behavior problems in premature children at school age. *Pediatrics*, *86*, 391-397.

Saigal, S., Szatmari, P., Rosenbaum, P., Campbell, D., & King, S. (1991). Cognitive abilities and school performance of extremely low birth weight children and matched term control children at age 8 years: a regional study. *The Journal of Pediatrics*, *118*, 751-760.

Saenger, P., Czernichow, P., Hughes, I., & Reiter, E. O. (2007). Small for gestational age: short stature and beyond. *Endocrine Reviews, 28*, 219-251.

Sansavini, A., Zavagli, V., Guarini, A., Savini, S., Alessandroni, R., & Faldella, G. (2015). Dyadic co-regulation, affective intensity and infant's development at 12 months: A comparison among extremely preterm and full-term dyads. *Infant Behavior and Development*, *40*, 29-40.

Sauce, B., & Matzel, L. D. (2018). The paradox of intelligence: Heritability and malleability coexist in hidden gene-environment interplay. *Psychological Bulletin, 144*, 26-47.

Scott, M. N., Taylor, H. G., Fristad, M. A., Klein, N., Espy, K. A., Minich, N., & Hack, M. (2012). Behavior disorders in extremely preterm/extremely low birth weight children in kindergarten. *Journal of Developmental and Behavioral Pediatrics*, *33*, 202.

Shenkin, S. D., Starr, J. M., & Deary, I. J. (2004). Birth weight and cognitive ability in childhood: a systematic review. *Psychological Bulletin*, *130*, 989.

Simpson, J. A., Collins, W. A., Tran, S., & Haydon, K. C. (2007). Attachment and the experience and expression of emotions in romantic relationships: a developmental perspective. *Journal of Personality and Social Psychology*, *92*, 355.

Singer, L. T., Salvator, A., Guo, S., Collin, M., Lilien, L., & Baley, J. (1999). Maternal psychological distress and parenting stress after the birth of a very low-birth-weight infant. *Journal of the American Medical Association*, *281*, 799-805.

Smith, K. E., Landry, S. H., & Swank, P. R. (2006). The role of early maternal responsiveness in supporting school-aged cognitive development for children who vary in birth status. *Pediatrics*, *117*, 1608-1617.

Sommerfelt, K., Andersson, H. W., Sonnander, K., Ahlsten, G., Ellertsen, B., Markestad, T., ... & Bakketeig, L. (2000). Cognitive development of term small for gestational age children at five years of age. *Archives of Disease in Childhood, 83*, 25-30.

Spiker, D., Ferguson, J., & Brooks-Gunn, J. (1993). Enhancing maternal interactive behavior and child social competence in low birth weight, premature infants. *Child Development*, *64*, 754-768.

Sroufe, L. A., Egeland, B., Carlson, E. A., & Collins, W. A. (2009). *The development of the person: The Minnesota study of risk and adaptation from birth to adulthood*. Guilford Press.

Strauss, R. S. (2000). Adult functional outcome of those born small for gestational age: twenty-six–year follow-up of the 1970 British birth cohort. *Journal of the American Medical Association*, *283*, 625-632.

Taylor, H. G., Klein, N., Minich, N. M., & Hack, M. (2000). Middle-school-age outcomes in children with very low birth weight. *Child Development*, *71*(6), 1495-1511.

Uzgiris, I. C., & Hunt, J. M. (1975). Assessment in infancy: Ordinal scales of psychological development. Champaign, IL: University of Illinois Press.

Vohr, B. R., Wright, L. L., Dusick, A. M., Mele, L., Verter, J., Steichen, J. J., ... & Delaney-Black, V. (2000). Neurodevelopmental and functional outcomes of extremely low birth weight infants in the National Institute of Child Health and Human Development Neonatal Research Network, 1993–1994. *Pediatrics*, *105*, 1216-1226.

Wechsler, D. (1967). *Manual for the Wechsler preschool and primary scale of intelligence*. Psychological Corporation.

Weiss, S. J., Wilson, P., Seed, M. S. J., & Paul, S. M. (2001). Early tactile experience of low birth weight children: Links to later mental health and social adaptation. *Infant and Child Development*, *10*, 93-115.

Wentzel, K. R. (1991). Relations between social competence and academic achievement in early adolescence. *Child Development*, *62*, 1066-1078.

Wolke, D., Jaekel, J., Hall, J., & Baumann, N. (2013). Effects of sensitive parenting on the academic resilience of very preterm and very low birth weight adolescents. *Journal of Adolescent Health*, *53*, 642-647.

Woodcock, R. W., Johnson, M. B., & Mather, N. (1990). *Woodcock-Johnson psycho-educational battery--Revise*d. DLM Teaching Resources.

Yang, S., Platt, R. W., & Kramer, M. S. (2010). Variation in child cognitive ability by week of gestation among healthy term births. *American Journal of Epidemiology*, *171*, 399-406.

Yu, Z. B., Han, S. P., Zhu, G. Z., Zhu, C., Wang, X. J., Cao, X. G., & Guo, X. R. (2011). Birth weight and subsequent risk of obesity: A systematic review and meta-analysis. *Obesity Reviews*, *12*, 525-542.

Zimmerman, I. L., Pond, R. E., & Steiner, V. G. (1979). *Preschool language scale manual*. CE Merrill Publishing Company. Chicago

Appendices

Table 1

Correlations Between Birth Weight, Gestational Age, Demographic Covariates and Cognitive Functioning

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Birth Weight	--																	
2. Gestational Age	**.52**	--																
3. Sex of Participant	-.04	.05	--															
4. Race of Participant	.07	.01	.01	--														
5. Maternal SES	-.12	-.11	-.06	.07	--													
6. Maternal Education	-.06	-.07	-.06	-.03	**.74**	--												
7. 24-Month Cog. Funct.	**.20**	.11	**.20**	.18	**.19**	**.24**	--											
8. 42-Month Cog. Funct.	**.22**	.08	**.16**	**.25**	**.18**	**.33**	**.65**	--										
9. 64-Month Cog. Funct.	**.23**	.05	.13	**.23**	**.27**	**.34**	**.58**	**.76**	--									
10. Grade 1 Cog Funct.	**.23**	.10	.10	**.21**	**.18**	**.28**	**.53**	**.71**	**.70**									
11. Grade 2 Cog. Funct	**.22**	.04	.09	**.21**	**.22**	**.28**	**.49**	**.65**	**.67**	**.89**	--							
12. Grade 3 Cog. Funct.	**.19**	-.04	.10	**.17**	**.18**	**.25**	**.46**	**.65**	**.63**	**.86**	**.92**	--						
13. Grade 6 Cog. Funct.	**.17**	.04	.13	.12	**.20**	**.36**	**.46**	**.64**	**.64**	**.81**	**.83**	**.86**	--					
14. 16-Year Cog. Funct.	**.20**	.12	**.09**	**.17**	**.32**	**.39**	**.26**	**.47**	**.45**	**.54**	**.49**	**.52**	**.59**	--				
15. 23-Year Cog. Funct.	.06	-.11	.19	.04	**.23**	**.33**	**.18**	**.32**	**.39**	**.32**	**.29**	**.35**	**.35**	**.38**	--			
16. 26-Year Cog. Funct.	.12	-.11	.12	.04	**.27**	**.39**	**.25**	**.39**	**.48**	**.44**	**.36**	**.44**	**.44**	**.44**	**.73**	--		
17. 32-Year Cog. Funct.	.10	-.07	.14	.05	**.24**	**.36**	**.17**	**.38**	**.41**	**.42**	**.36**	**.44**	**.44**	**.47**	**.59**	**.83**	--	
18. 34-Year Cog. Funct.	.10	-.09	**.20**	-.02	**.22**	**.36**	.14	**.42**	**.45**	**.45**	**.37**	**.45**	**.45**	**.46**	**.59**	**.81**	**.91**	--

For participant race, 1 = White/non-Hispanic, 0 = non-White. For participant sex, 1 = female, 0 = male.

Table 2

Correlations Between Birth Weight, Gestational Age, Demographic Covariates and Cognitive Functioning

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Birth Weight	--													
2. Gestational Age	**.52**	--												
3. Sex of Participant	-.04	.05	--											
4. Race of Participant	.07	.01	.01	--										
5. Maternal SES	-.12	-.11	-.06	.07	--									
6. Maternal Education	-.06	-.07	.04	-.03	**.74**	--								
7. Kindergarten Social Comp.	.01	-.09	.04	.13	.08	.07	--							
8. Grade 1 Social Comp.	.01	-.03	**.12**	.06	.12	.17	**.45**	--						
9. Grade 2 Social Comp.	-.04	-.02	**.12**	**.08**	.11	.17	**.41**	**.48**	--					
10. Grade 3 Social Comp.	-.05	.01	**.19**	**.13**	**.15**	.19	**.41**	**.54**	**.55**	--				
11. Grade 6 Social Comp.	-.11	-.01	**.21**	**.00**	**.23**	**.29**	**.31**	**.40**	**.33**	**.40**	--			
12. Age 16 Social Comp.	.00	-.10	**.18**	**.00**	.30	**.29**	**.25**	**.29**	**.23**	**.36**	**.35**	--		
13. Age 23 Relationship Comp.	-.08	-.15	**.14**	**.09**	**.06**	.12	**.22**	**.32**	**.18**	.09	**.26**	**.23**	--	
14. Age 32 Relationship Comp.	.05	-.01	**.00**	**.00**	**.15**	**.17**	**.21**	**.24**	**.26**	**.23**	**.25**	**.19**	**.42**	--

For participant race, 1 = White/non-Hispanic, 0 = non-White. For participant sex, 1 = female, 0 = male.

Table 3

Estimates of the Influence of Birth Weight on Cognitive Functioning throughout Childhood, Adolescence and Adulthood

	Model Fit					Model Comparison		
Model	χ^2	*df*	*SRMR*	CFI	RMSEA 90% CI	$\Delta\chi^2$	*df*	*p*
Basic Model						2.72	1	.10
A. Enduring Effects	165.28	65	.162	.948	.062-.091	--	--	--
B. Revisionist	168.01	66	.166	.947	.063-.091	--	--	--
Model with demographic covariates						4.48	1	.03
A. Enduring Effects	251.31	109	.140	.929	.059-.081	--	--	--
B. Revisionist	255.79	110	.143	.928	.059-.082	--	--	--
Model with stability paths						.96	1	.33
A. Enduring Effects	76.06	55	.083	.989	.012-.058	--	--	--
B. Revisionist	77.02	56	.085	.989	.011-.057	--	--	--
Model with demographic covariates and stability paths						2.08	1	.15
A. Enduring Effects	178.53	99	.106	.961	.042-.068	--	--	--
B. Revisionist	180.61	100	.107	.960	.042-.068	--	--	--

Table 4

Estimates of the Influence of Gestational Age on Cognitive Functioning throughout Childhood, Adolescence and Adulthood

	Model Fit					Model Comparison		
Model	χ^2	*df*	SRMR	CFI	RMSEA 90% CI	$\Delta\chi^2$	*df*	*p*
Basic Model						.98	1	.32
C. Enduring Effects	170.42	65	.167	.945	.064-.093	--	--	--
D. Revisionist	171.40	66	.166	.945	.064-.093	--	--	--
Model with demographic covariates						.52	1	.47
C. Enduring Effects	254.20	109	.144	.928	.059-.082	--	--	--
D. Revisionist	254.73	110	.144	.928	.059-.082	--	--	--
Model with stability paths						1.82	1	.18
C. Enduring Effects	78.66	55	.086	.988	.017-.060	--	--	--
D. Revisionist	80.49	56	.087	.987	.018-.060	--	--	--
Model with demographic covariates and stability paths						1.21	1	.27
C. Enduring Effects	178.39	99	.109	.960	.042-.068	--	--	--
D. Revisionist	179.60	100	.108	.960	.042-.067	--	--	--

Table 5
Estimates of the Influence of Birth Weight on Social Competence throughout Childhood, Adolescence and Adulthood

	Model Fit					Model Comparison		
Model	χ^2	*df*	*SRMR*	CFI	RMSEA 90% CI	$\Delta\chi^2$	*df*	*p*
Basic Model						.64	1	.42
E. Enduring Effects	101.25	27	.135	.758	.082-.125	--	--	--
F. Revisionist	101.89	28	.136	.759	.080-.122	--	--	--
Model with demographic covariates						.78	1	.38
E. Enduring Effects	122.87	55	.089	.803	.052-.084	--	--	--
F. Revisionist	123.65	56	.090	.804	.051-.083	--	--	--
Model with stability paths						.63	1	.43
E. Enduring Effects	38.61	21	.073	.943	.027-.085	--	--	--
F. Revisionist	39.24	22	.074	.944	.025-.082	--	--	--
Model with demographic covariates and stability paths						.76	1	.38
E. Enduring Effects	68.84	49	.059	.942	.012-.059	--	--	--
F. Revisionist	69.60	50	.059	.943	.011-.058	--	--	--

Table 6

Estimates of the Influence of Gestational Age on Social Competence throughout Childhood, Adolescence and Adulthood

	Model Fit					Model Comparison		
Model	χ^2	*df*	*SRMR*	CFI	RMSEA 90% CI	$\Delta\chi^2$	*df*	*p*
Basic Model						.41	1	.52
G. Enduring Effects	101.89	27	.135	.758	.082-.125	--	--	--
H. Revisionist	102.29	28	.137	.760	.080-.122	--	--	--
Model with demographic covariates						.32	1	.57
G. Enduring Effects	86.86	55	.077	.840	.041-.079	--	--	--
H. Revisionist	87.18	56	.078	.843	.040-.078	--	--	--
Model with stability paths						.12	1	.73
G. Enduring Effects	39.01	21	.074	.942	.028-.085	--	--	--
H. Revisionist	39.13	22	.075	.945	.025-.082	--	--	--
Model with demographic covariates and stability paths						.06	1	.80
G. Enduring Effects	68.12	49	.059	.945	.010-.059	--	--	--
H. Revisionist	69.19	50	.059	.947	.006-.057	--	--	--

Table 7

Estimates of the Influence of Birth Weight on Cognitive Functioning throughout Childhood, Adolescence and Adulthood Controlling for Gestational Age

	Model Fit					Model Comparison		
Model	χ^2	*df*	*SRMR*	CFI	RMSEA 90% CI	$\Delta\chi^2$	*df*	*p*
Basic Model						6.69	1	.01
I. Enduring Effects	173.39	76	.152	.949	.056-.084	--	--	--
J. Revisionist	180.08	77	.159	.946	.058-.085	--	--	--
Model with demographic covariates						8.71	1	.003
I. Enduring Effects	259.72	120	.132	.931	.055-.077	--	--	--
J. Revisionist	268.43	121	.136	.927	.057-.078	--	--	--
Model with stability paths						4.03	1	.04
I. Enduring Effects	84.25	66	.080	.991	.000-.052	--	--	--
J. Revisionist	88.28	67	.084	.985	.007-.053	--	--	--
Model with demographic covariates and stability paths						5.65	1	.01
I. Enduring Effects	186.94	110	.100	.962	.038-.064	--	--	--
J. Revisionist	192.59	111	.102	.960	.040-.065	--	--	--

Figure 1

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning

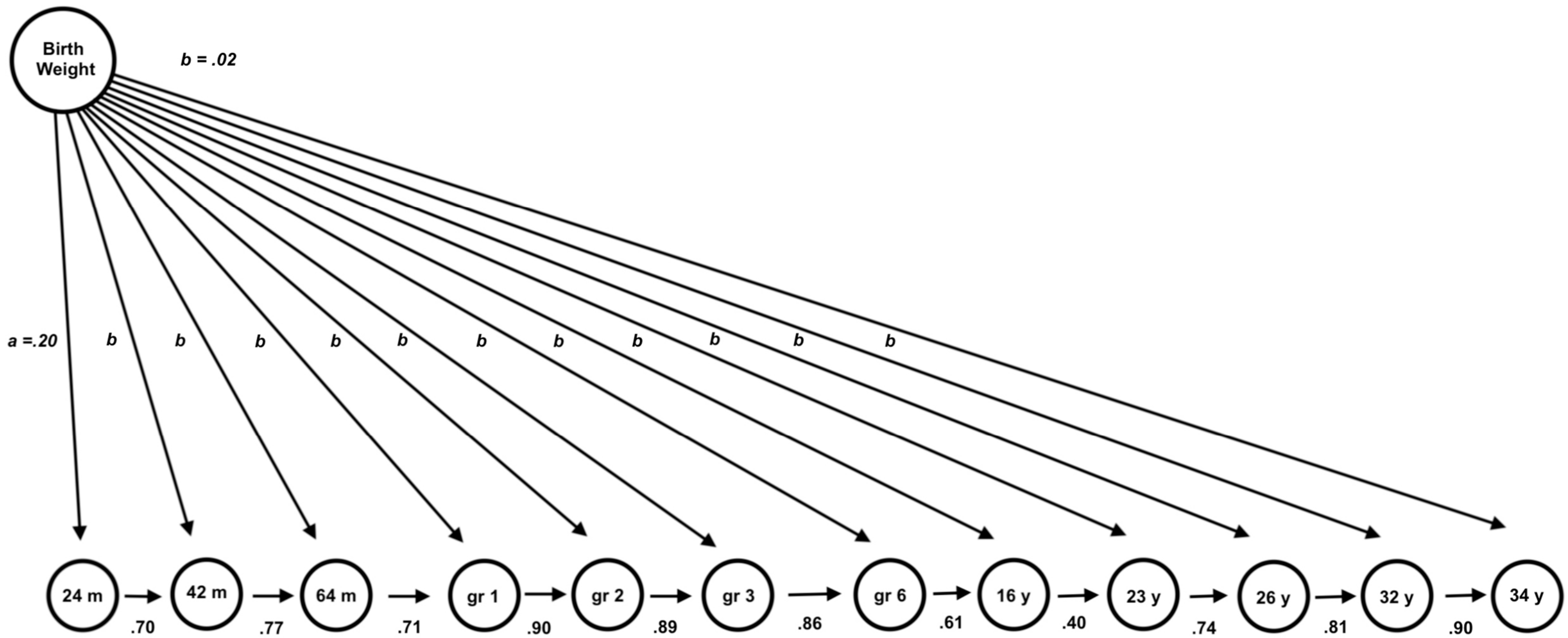


Figure 2

Illustration of Enduring Effects Model for Gestational Age Predicting Cognitive Functioning

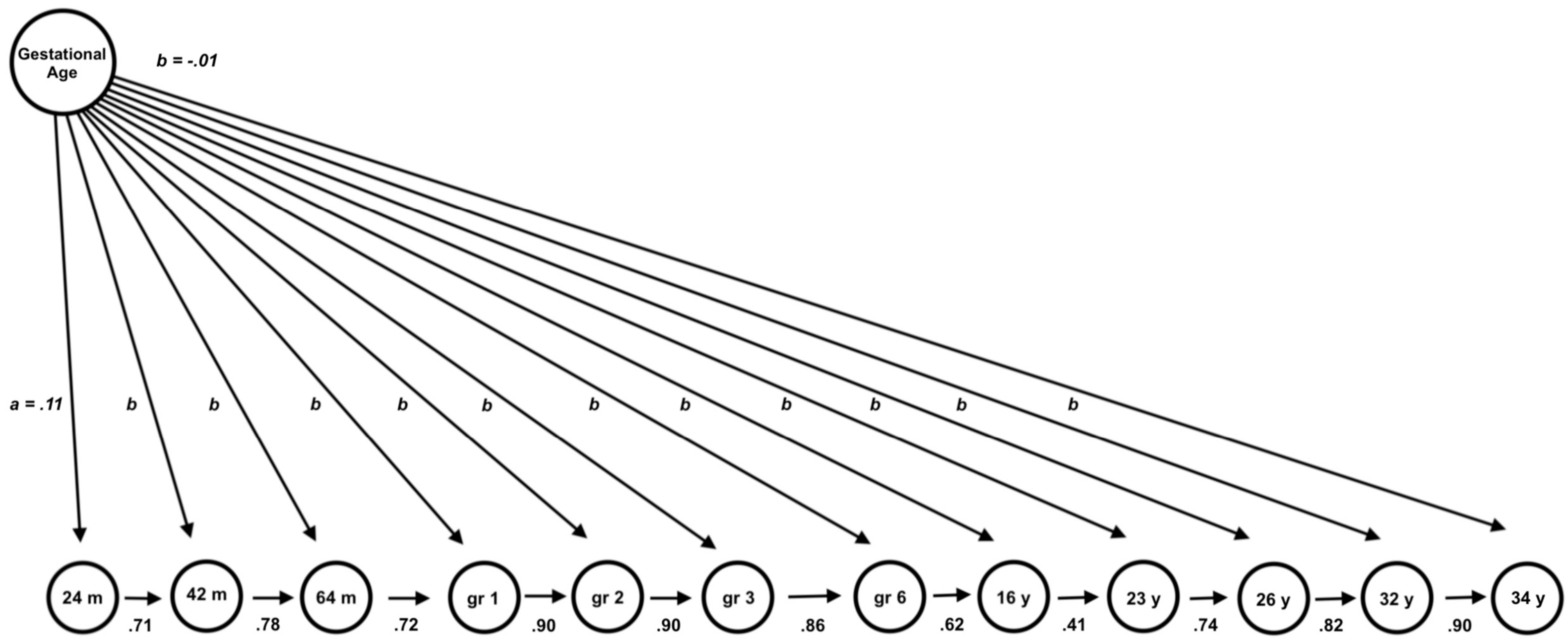


Figure 3

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Controlling for Demographic Covariates

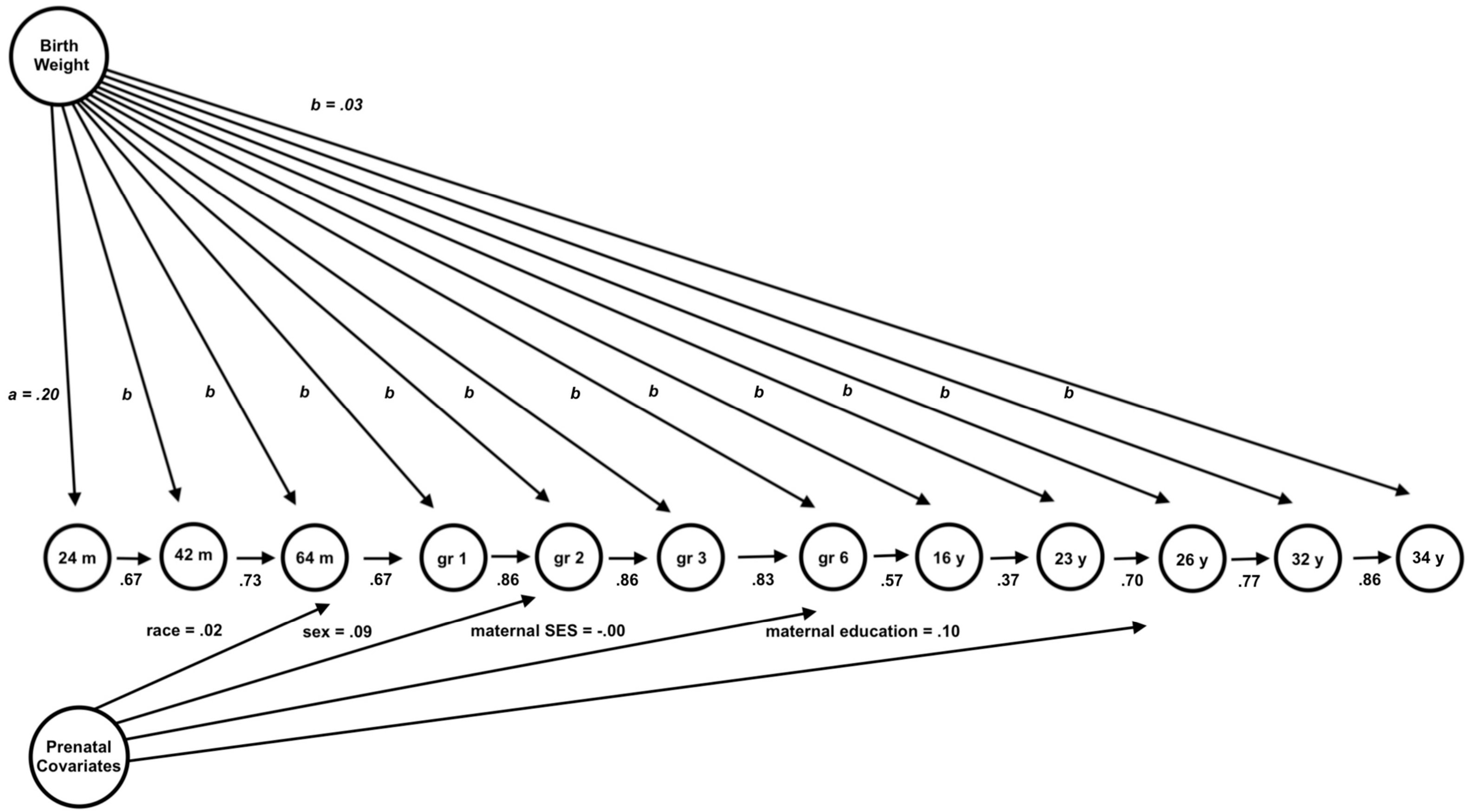


Figure 4

Illustration of Enduring Effects Model for Gestational Age Predicting Cognitive Functioning Controlling for Demographic Covariates

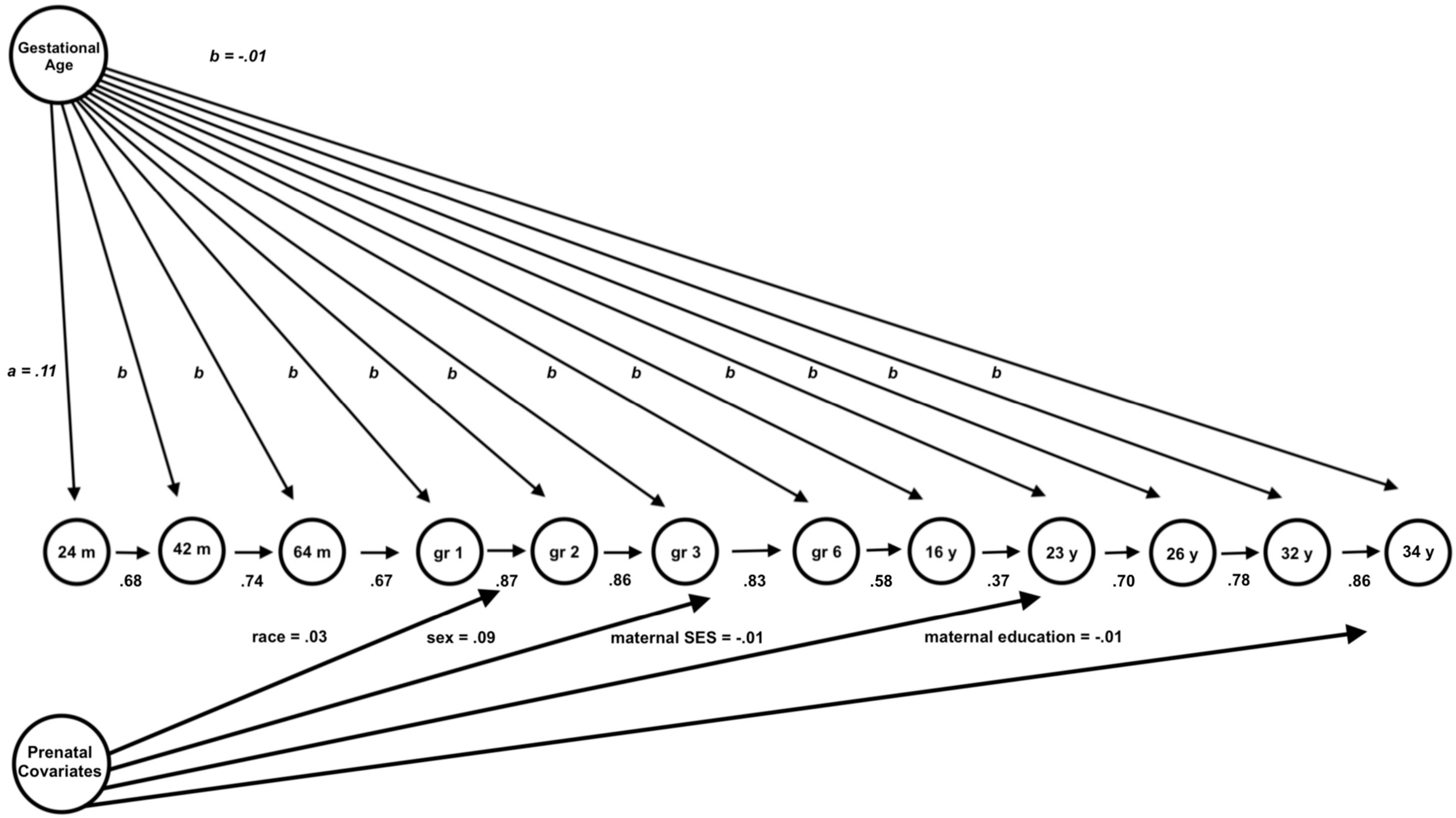


Figure 5

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Accounting for Second-Order Stability

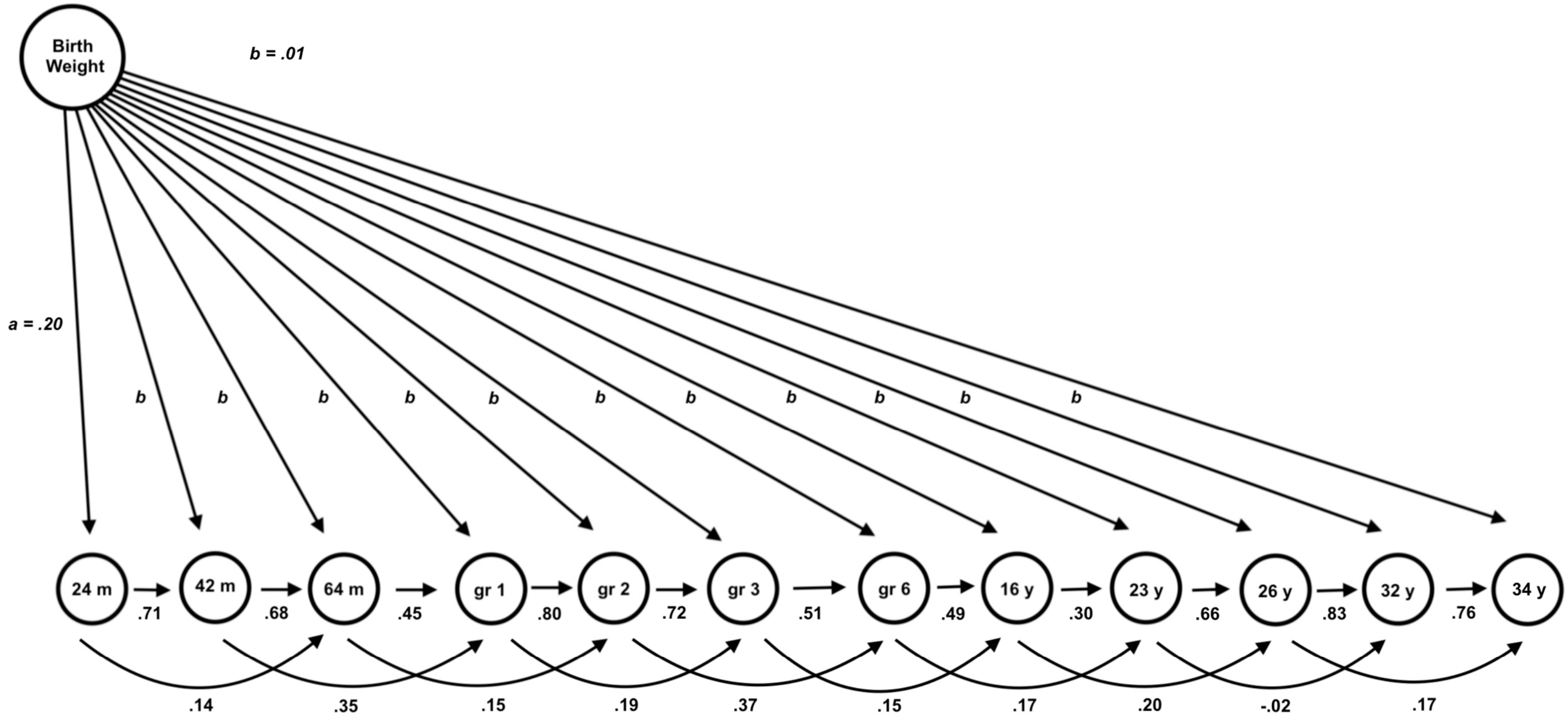


Figure 6

Illustration of Enduring Effects Model for Gestational Age Predicting Cognitive Functioning Accounting for Second-Order Stability

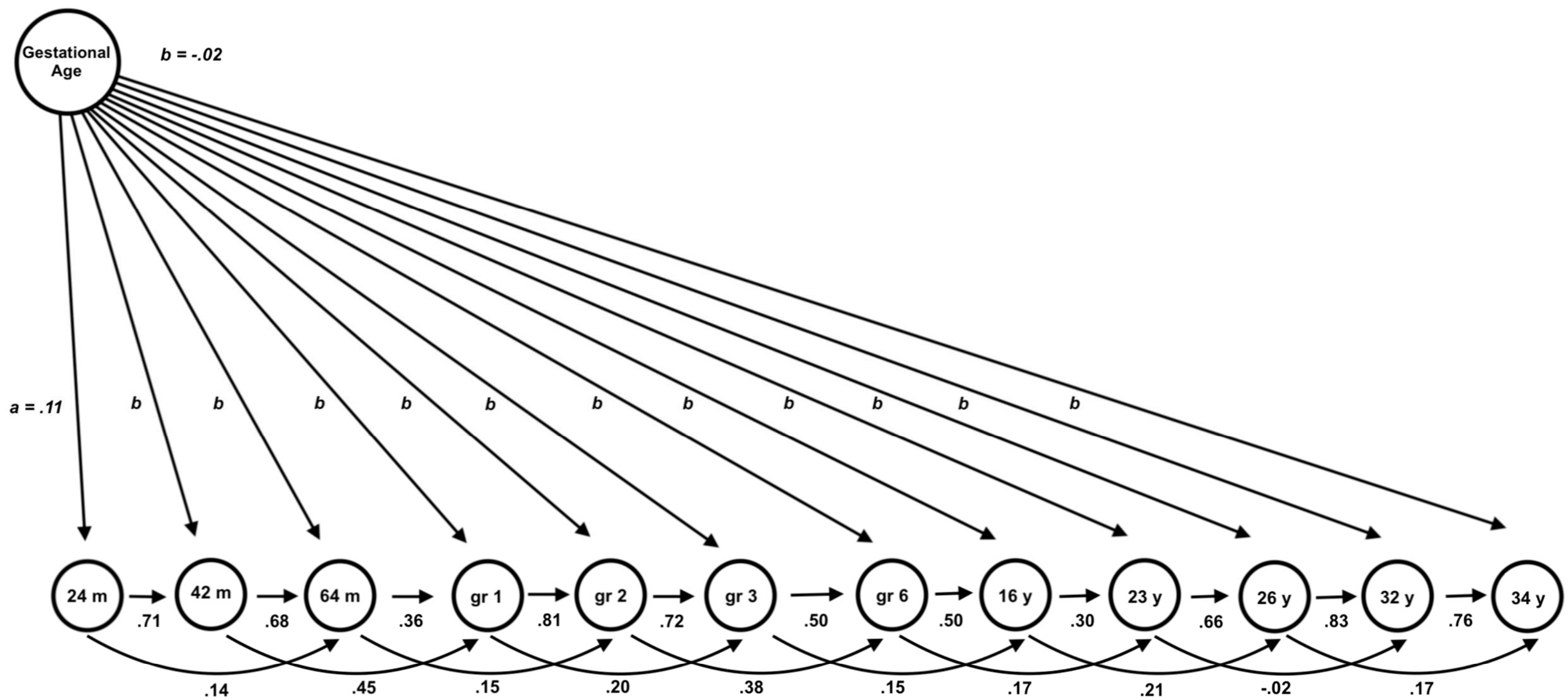


Figure 7

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Accounting for Second-Order Stability and Demographic Covariates

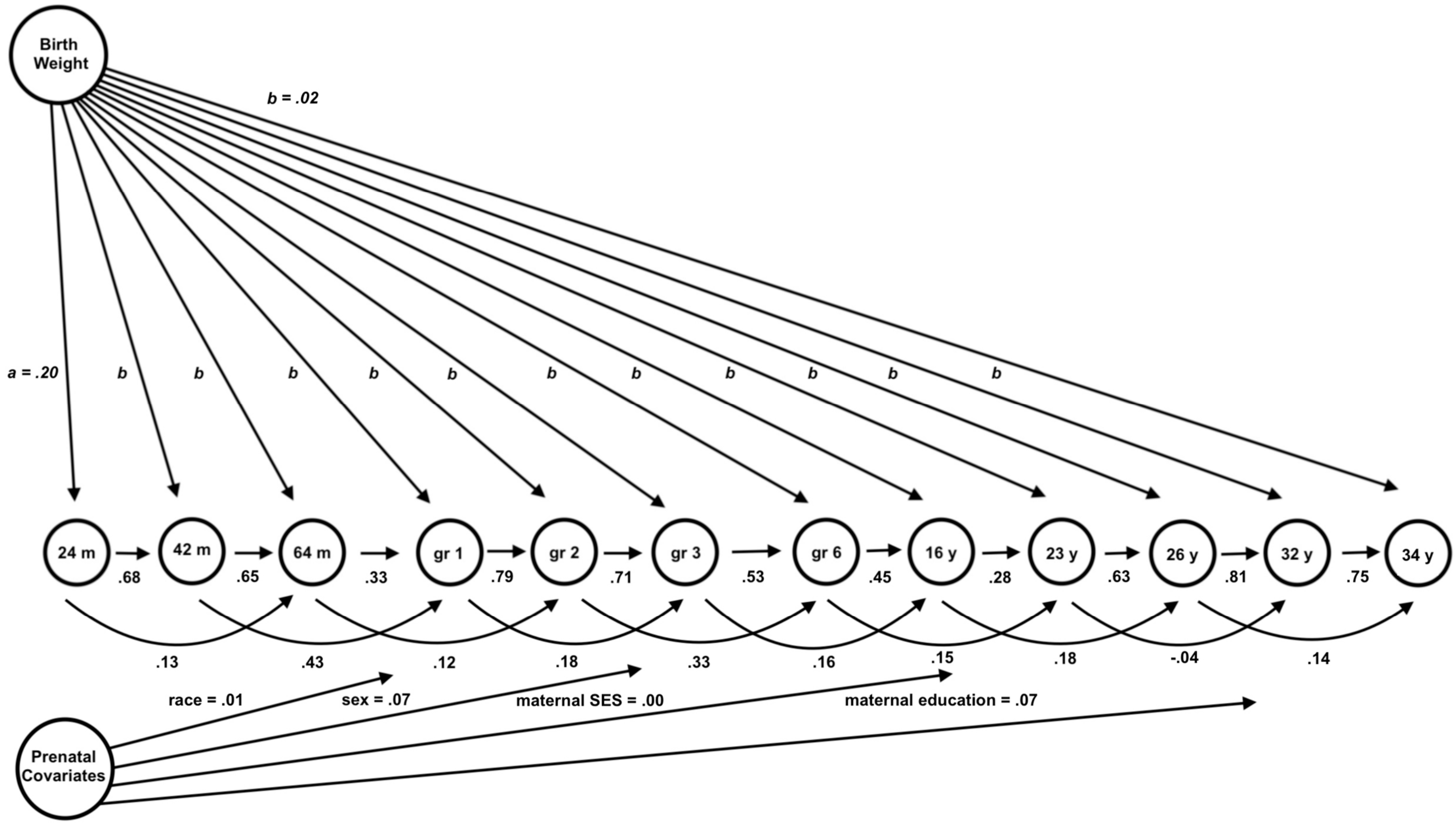


Figure 8
Illustration of Enduring Effects Model for Gestational Age Predicting Cognitive Functioning Accounting for Second-Order Stability and Demographic Covariates

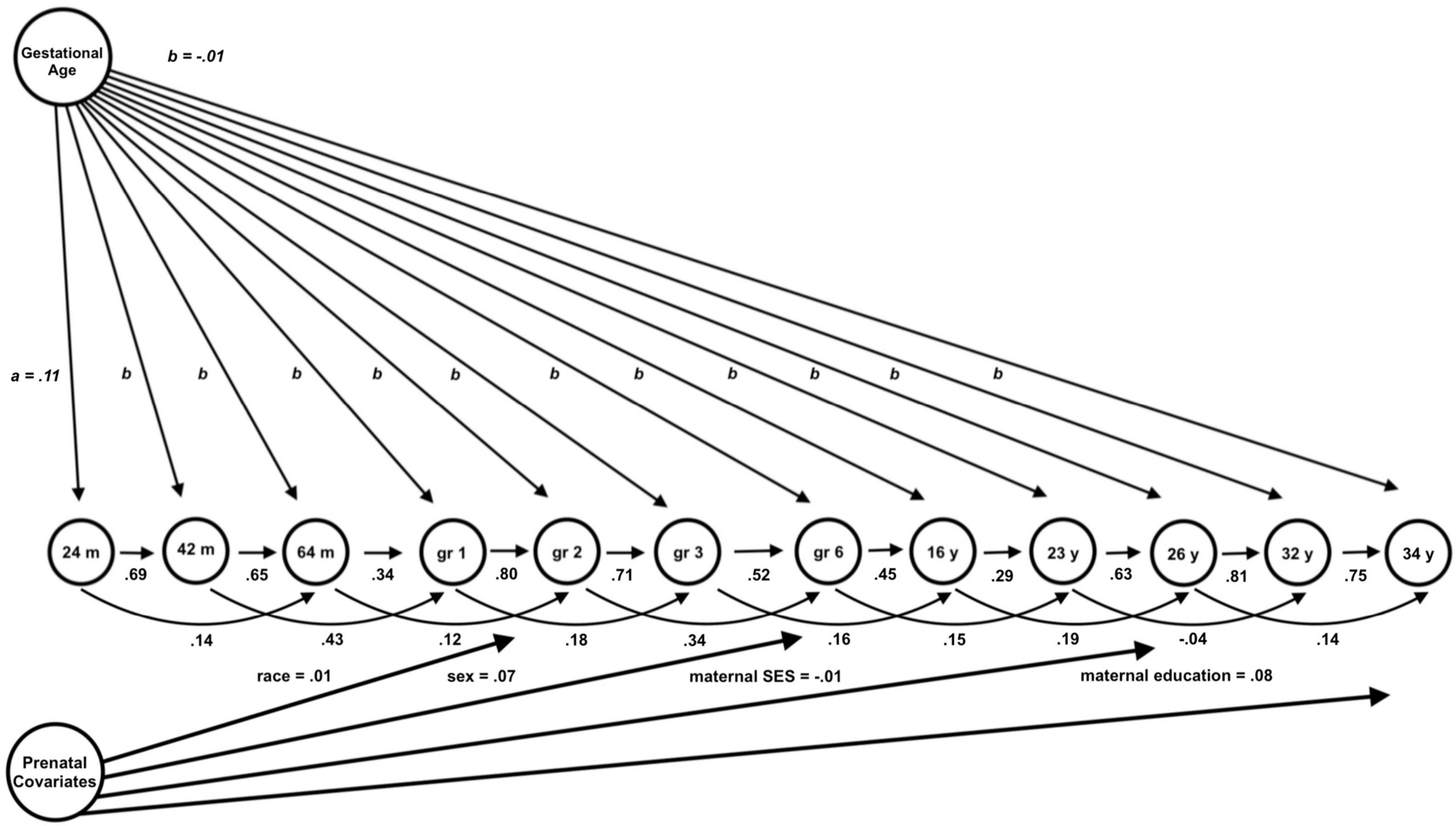


Figure 9

Illustration of Enduring Effects Model for Birth Weight Predicting Social Functioning

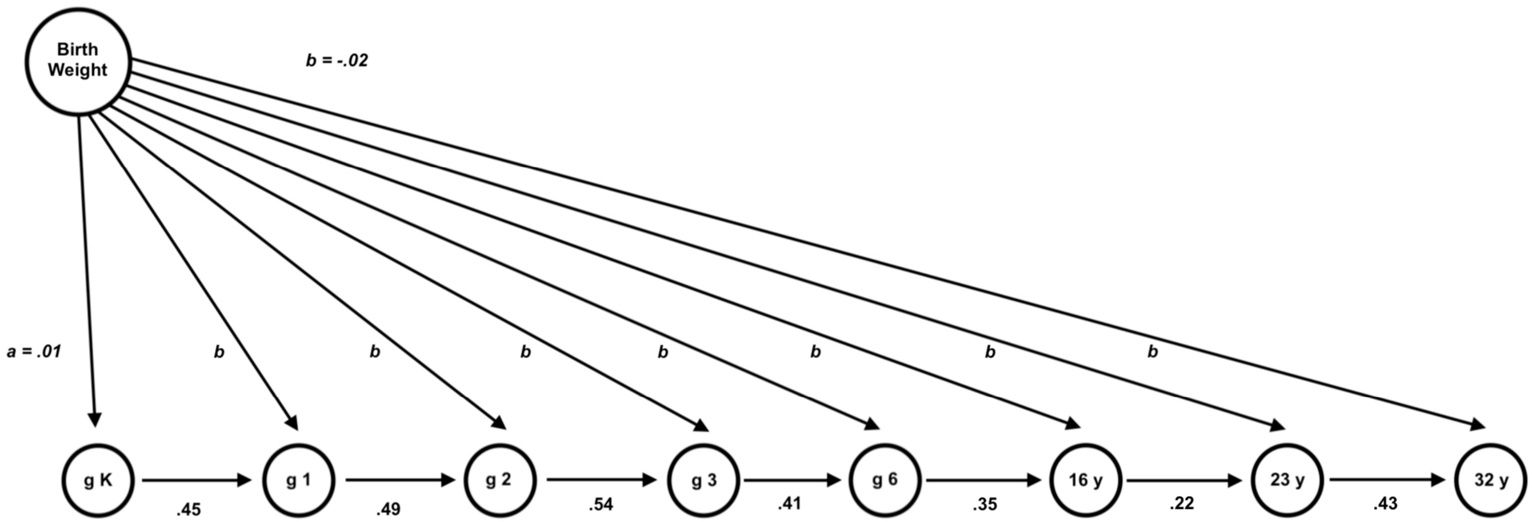


Figure 10

Illustration of Enduring Effects Model for Gestational Predicting Social Functioning

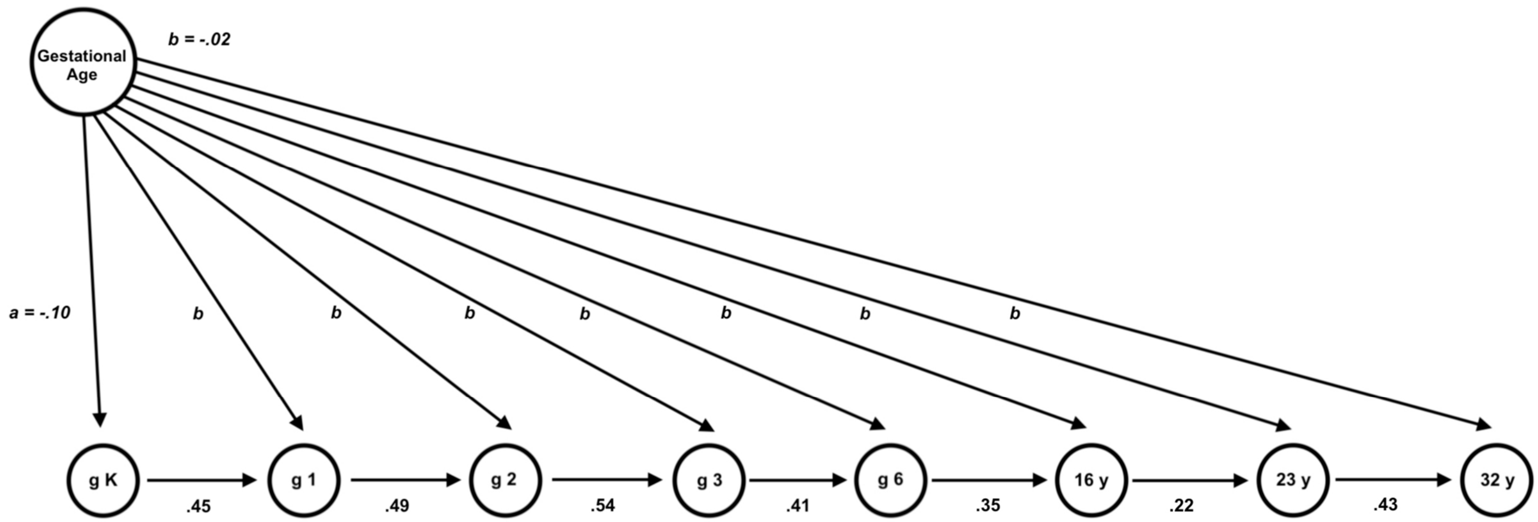


Figure 11

Illustration of Enduring Effects Model for Birth Weight Predicting Social Functioning Controlling for Demographic Covariates

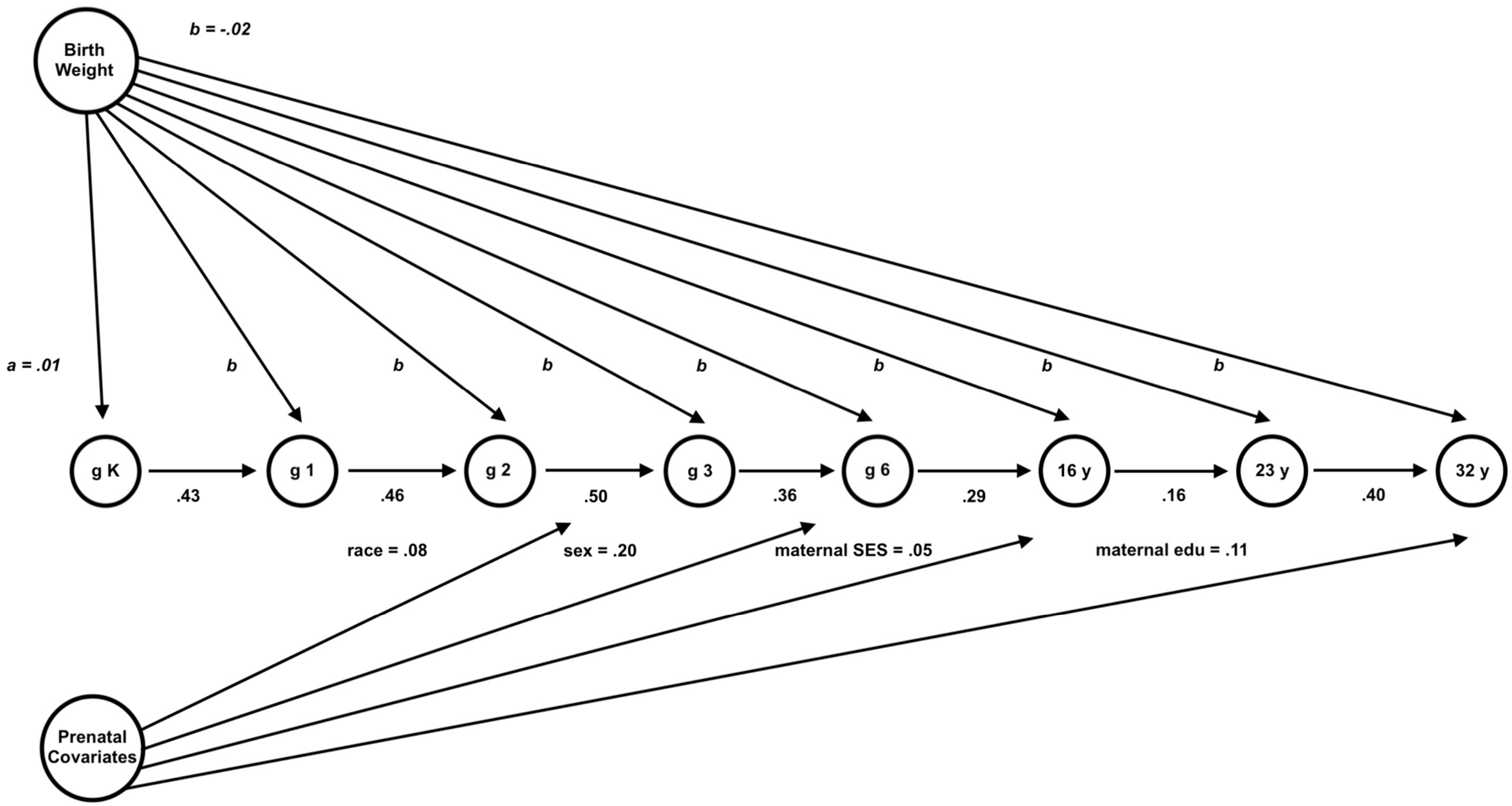


Figure 12

Illustration of Enduring Effects Model for Gestational Age Predicting Social Functioning Controlling for Demographic Covariates

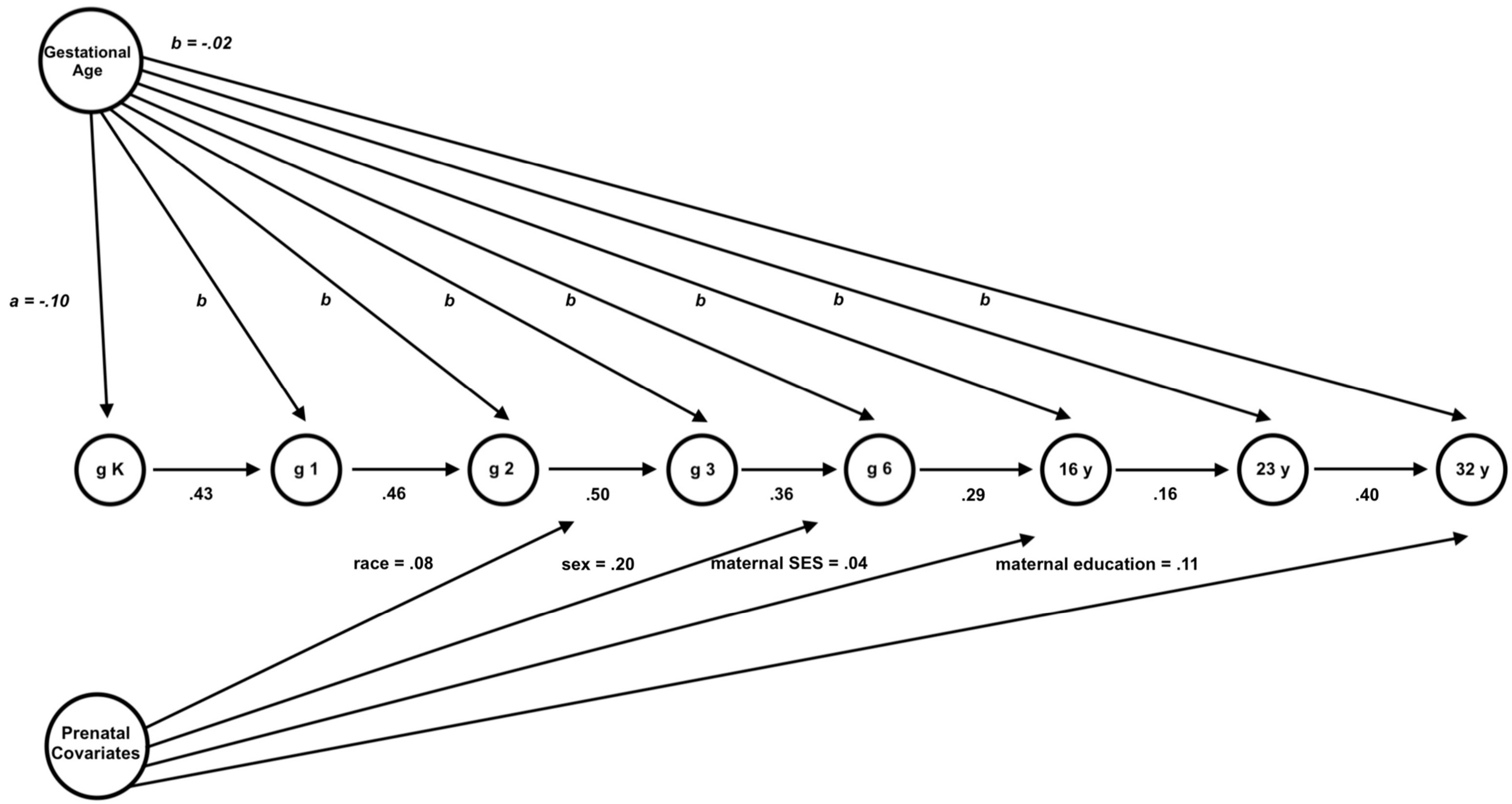


Figure 13

Illustration of Enduring Effects Model for Birth Weight Predicting Social Functioning Accounting for Second-Order Stability

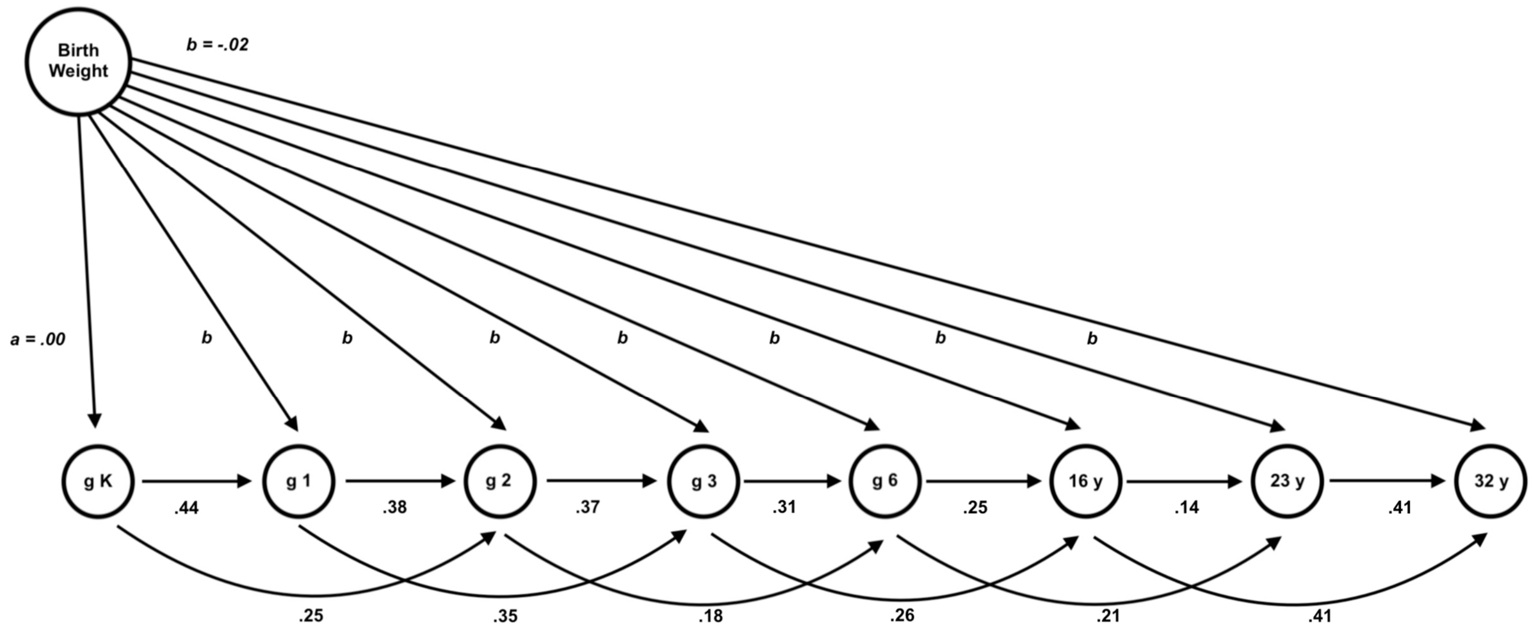


Figure 14

Illustration of Enduring Effects Model for Gestational Age Predicting Social Functioning Accounting for Second-Order Stability

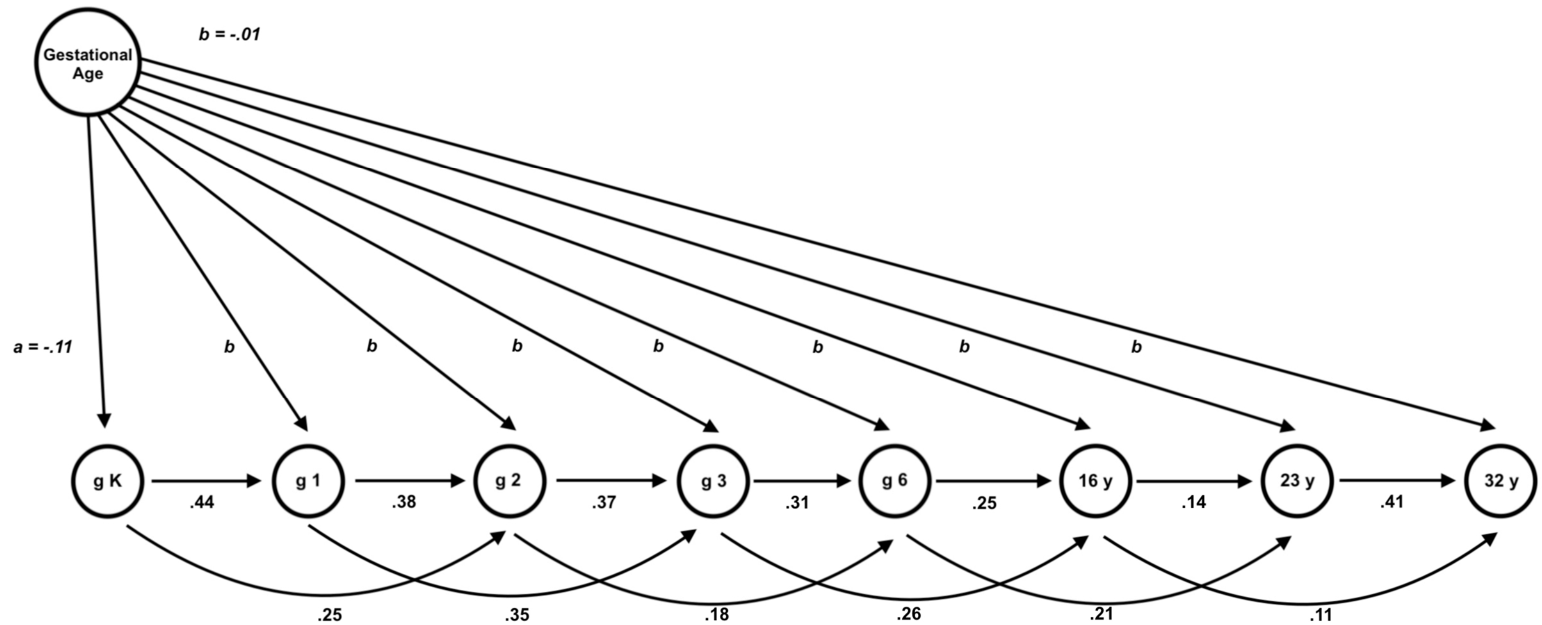


Figure 15

Illustration of Enduring Effects Model for Birth Weight Predicting Social Functioning Accounting for Second-Order Stability and Demographic Covariates

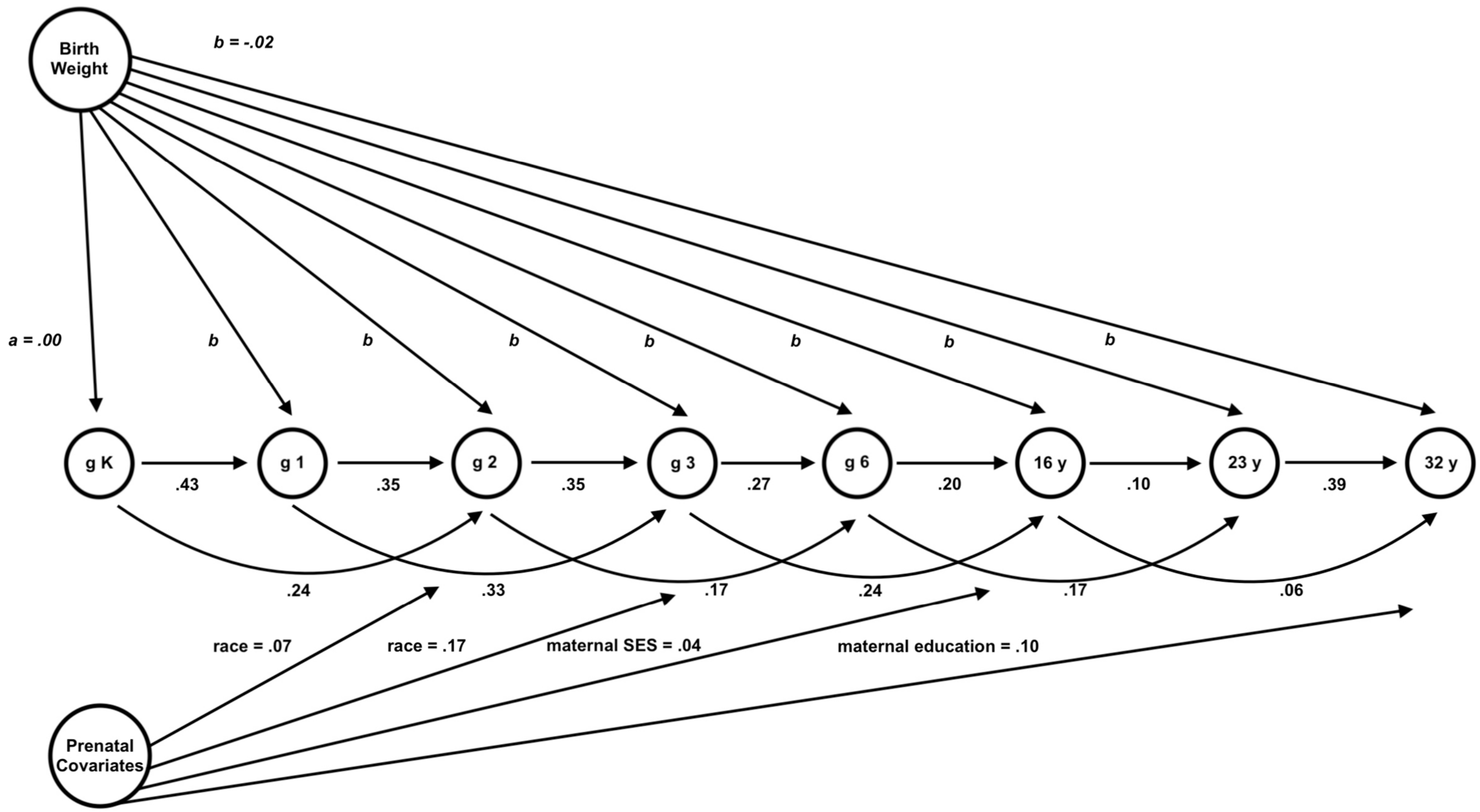


Figure 16

Illustration of Enduring Effects Model for Gestational Age Predicting Social Functioning Accounting for Second-Order Stability and Demographic Covariates

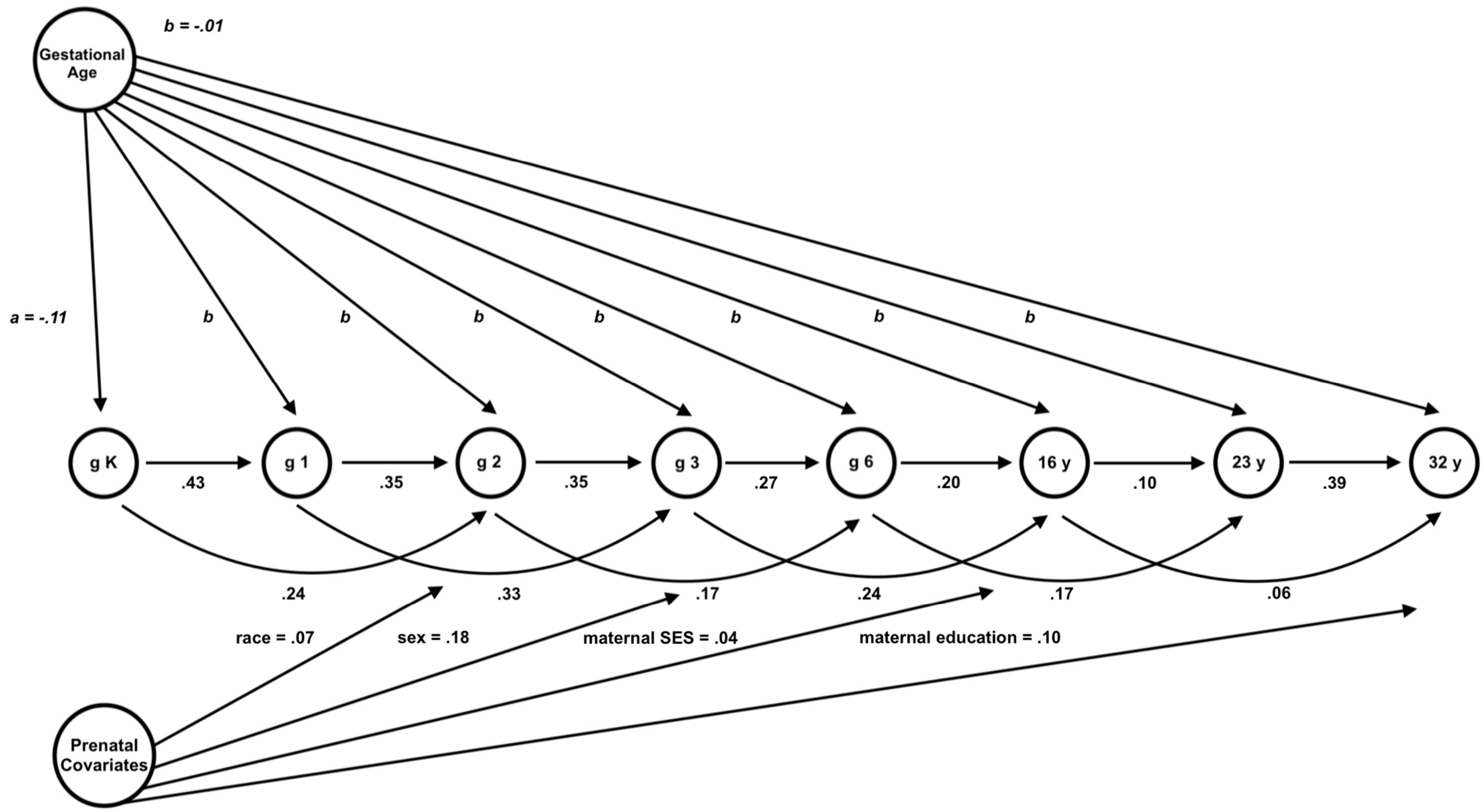


Figure 17

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Controlling for Gestational Age

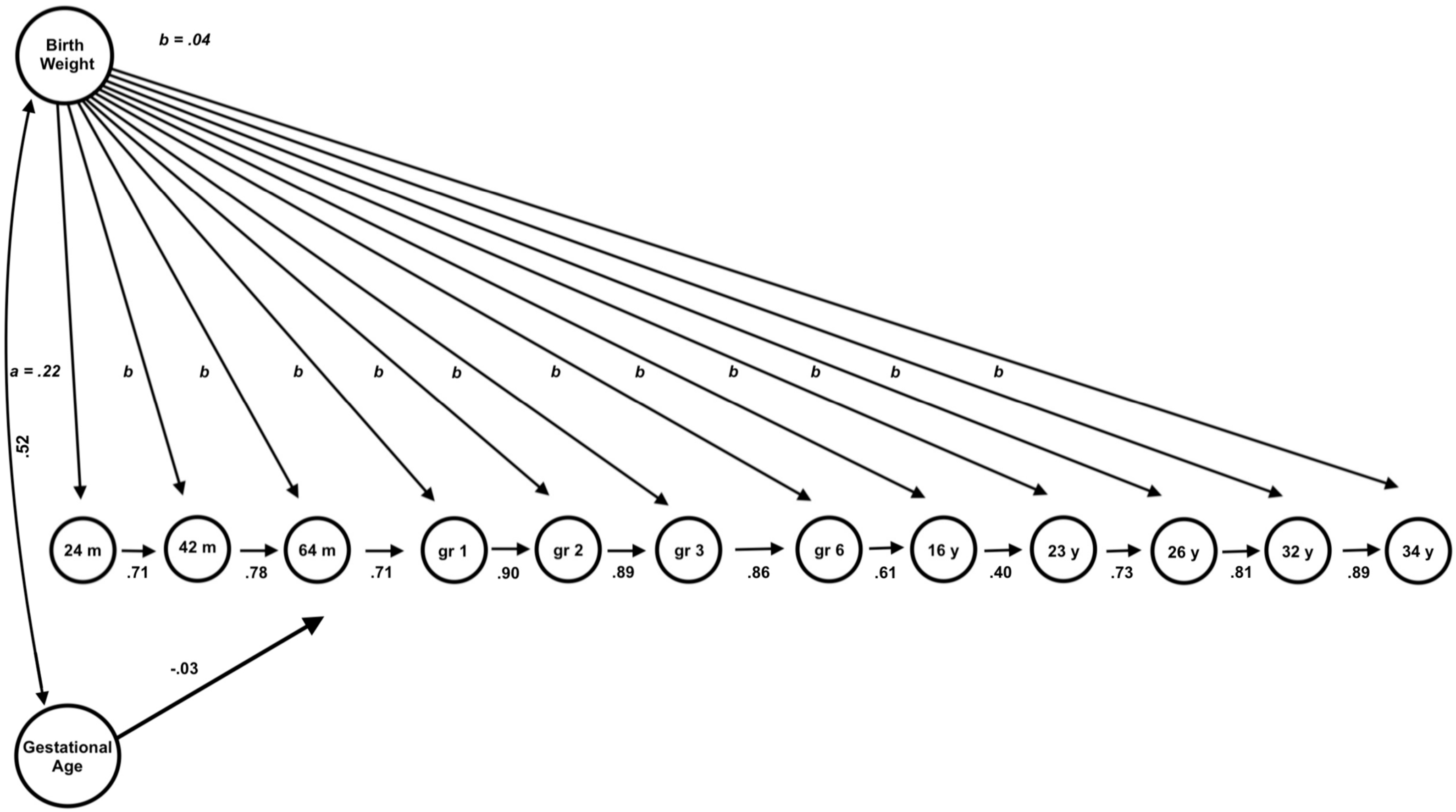


Figure 18

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Controlling for Gestational Age and Demographic Covariates

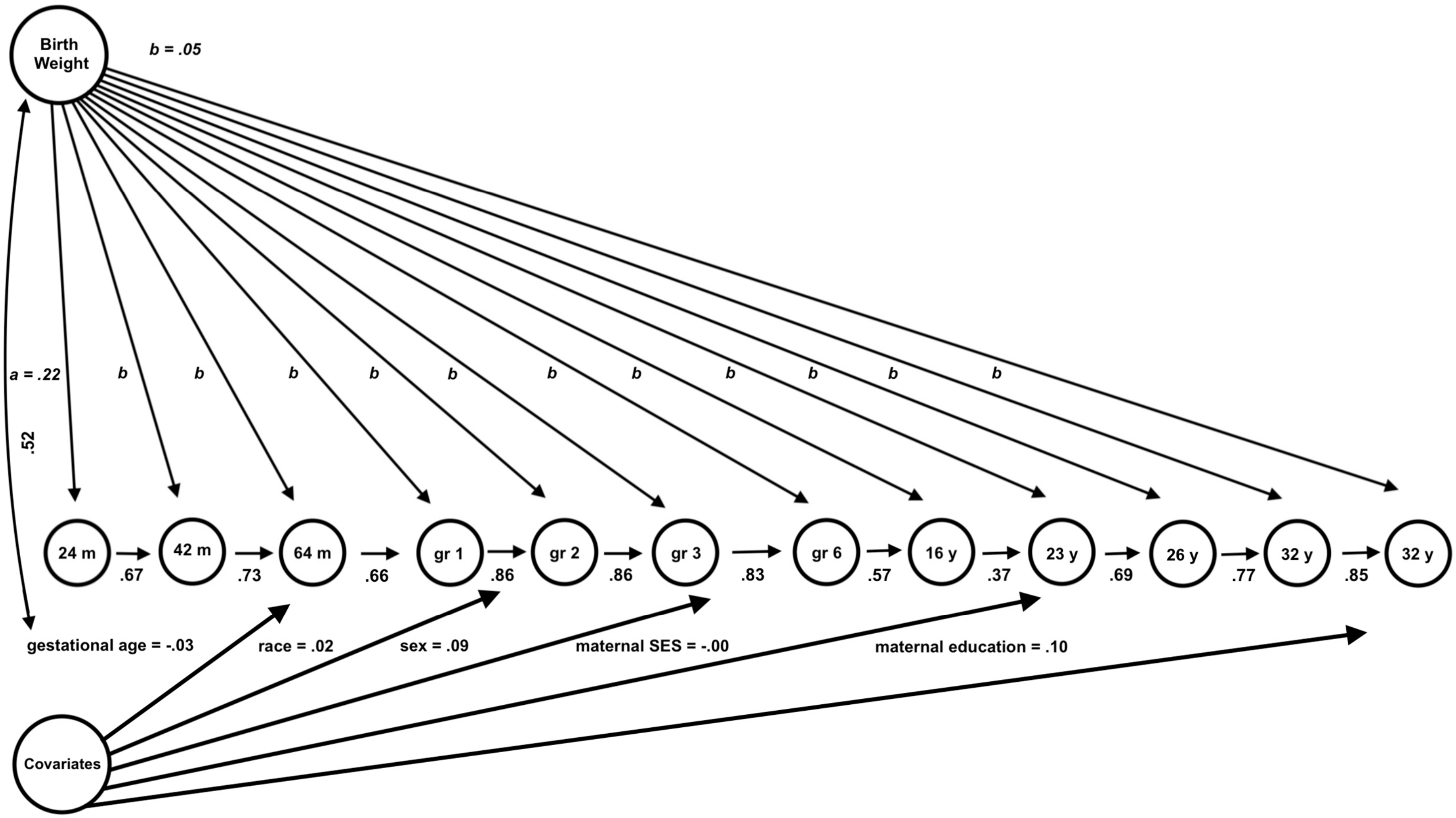


Figure 19

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Accounting for Gestational Age and Second-Order Stability

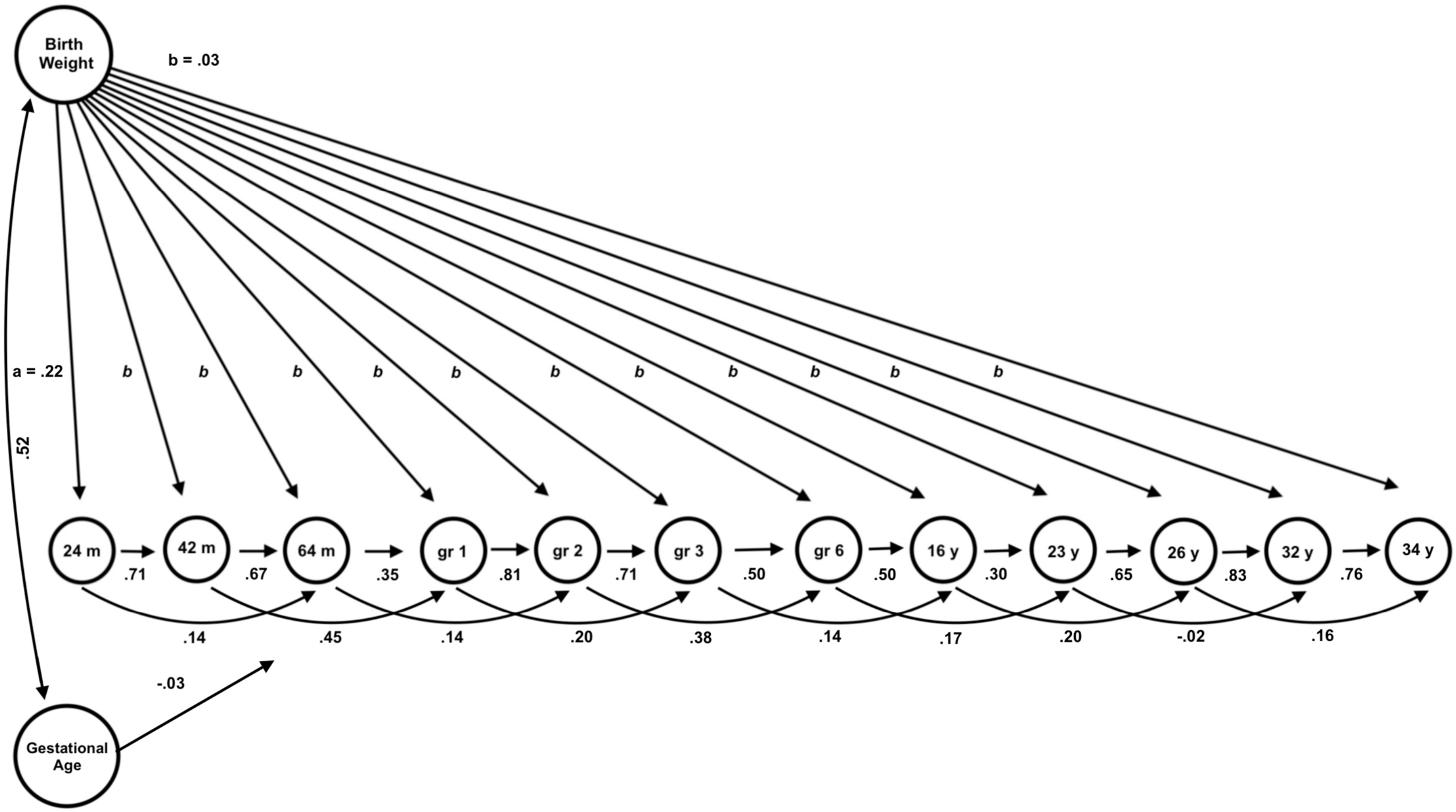
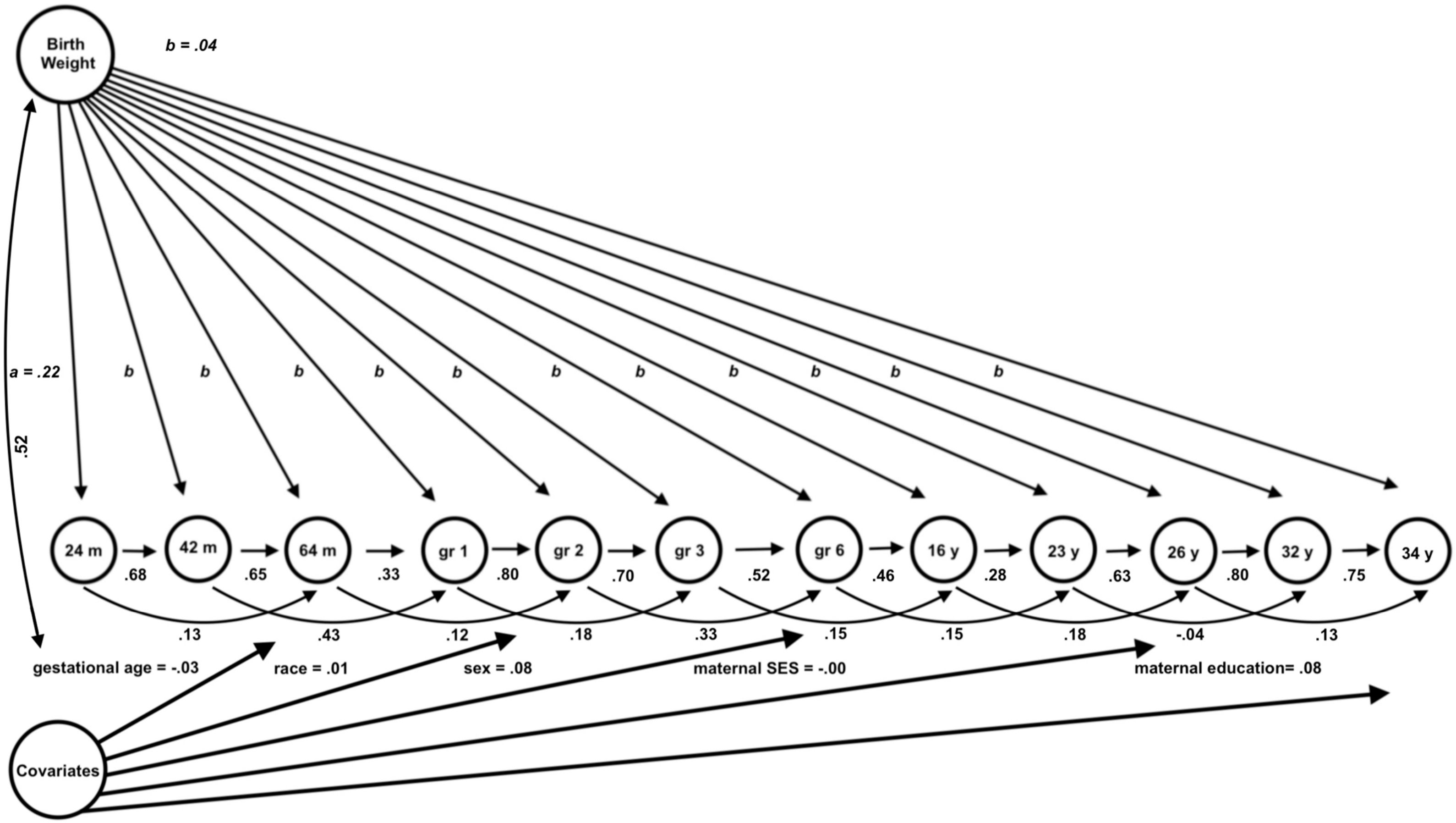


Figure 20

Illustration of Enduring Effects Model for Birth Weight Predicting Cognitive Functioning Accounting for Gestational Age, Demographic Covariates and Second-Order Stability



Appendix A:
Analysis Script for Cognitive Functioning Descriptive Statistics

```
library(readr)
library(Hmisc)
library(ggplot2)

MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)

MLSRA_BW$BWGrams_z = scale(MLSRA_BW$BWGrams)
hist(MLSRA_BW$BWGrams_z)

describe(MLSRA_BW$BWGrams)
describe(MLSRA_BW$GestAgeBirth)
describe(MLSRA_BW$bayleyindex24)
describe(MLSRA_BW$zimmerman_language42)
describe(MLSRA_BW$wppsi_total64)
describe(MLSRA_BW$piat_1st_age)
describe(MLSRA_BW$piat_2nd_age)
describe(MLSRA_BW$piat_3rd_age)
describe(MLSRA_BW$piat_6th_age)
describe(MLSRA_BW$wjc_16_age)
describe(MLSRA_BW$attain23)
describe(MLSRA_BW$attain26)
describe(MLSRA_BW$attain32)
describe(MLSRA_BW$attain34)

hist(MLSRA_BW$BWGrams)
hist(MLSRA_BW$GestAgeBirth)
hist(MLSRA_BW$bayleyindex24)
hist(MLSRA_BW$zimmerman_language42)
hist(MLSRA_BW$wppsi_total64)
hist(MLSRA_BW$piat_1st_age)
hist(MLSRA_BW$piat_2nd_age)
hist(MLSRA_BW$piat_3rd_age)
hist(MLSRA_BW$piat_6th_age)
hist(MLSRA_BW$wjc_16_age)
hist(MLSRA_BW$attain23)
hist(MLSRA_BW$attain26)
hist(MLSRA_BW$attain32)
hist(MLSRA_BW$attain34)


# Associations with Outcomes -------------------------


Cog.mat=as.matrix(MLSRA_BW
                  [,c("BWGrams_z",
```

```
                      "GestAgeBirth",
                      "bayleyindex24",
                      "zimmerman_language42",
                      "wppsi_total64",
                      "piat_1st_age",
                      "piat_2nd_age",
                      "piat_3rd_age",
                      "piat_6th_age",
                      "wjc_16_age",
                      "attain23",
                      "attain26",
                      "attain32",
                      "attain34")])



rcorr(Cog.mat)

# Associations with Covariates ----------------------------
covar.mat.cog=as.matrix(MLSRA_BW
                        [,c("BWGrams_z",
                            "GestAgeBirth_z",
                            "sex",
                            "race",
                            "ses_prn",
                            "mat_edu_prn")])

rcorr(covar.mat.cog)



# Correlations with Cog and CoVars ------------------------
covar.cog=as.matrix(MLSRA_BW
                        [,c("sex",
                            "race",
                            "ses_prn",
                            "mat_edu_prn",
                            "bayleyindex24",
                            "zimmerman_language42",
                            "wppsi_total64",
                            "piat_1st_age",
                            "piat_2nd_age",
                            "piat_3rd_age",
                            "piat_6th_age",
                            "wjc_16_age",
                            "attain23",
                            "attain26",
                            "attain32",
                            "attain34")])

rcorr(covar.cog)
```

```
Cog.cor=rcorr(Cog.mat)
BW.Cog.r=c(Cog.cor$r[1,3:14])
as.matrix(BW.Cog.r)
GA.Cog.r=c(Cog.cor$r[2,3:14])
as.matrix(GA.Cog.r)

BW.Cog.p=c(Cog.cor$P[1,3:14])
as.matrix(BW.Cog.p)
GA.Cog.p=c(Cog.cor$P[2,3:14])
as.matrix(GA.Cog.p)

plot(x = BW.Cog.r,
     xlab= "Assessment",
     ylab = "Correlation with Birth Weight")

plot(x = GA.Cog.r,
     xlab= "Assessment",
     ylab = "Correlation with Gestational Age")

ggplot(MLSRA_BW, aes(x=BWGrams, y=bayleyindex24))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Bayley Scales of Infant
Development")+
  ggtitle("Birth Weight and Cognitive Functioning at 24
Months")

ggplot(MLSRA_BW, aes(x=BWGrams, y=zimmerman_language42))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Zimmerman Language Scale")+
  ggtitle("Birth Weight and Cognitive Functioning at 24
Months")

ggplot(MLSRA_BW, aes(x=BWGrams, y=wppsi_total64))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Wechlser Preschool and Primary Scale
of Intelligence")+
  ggtitle("Birth Weight and Cognitive Functioning at 64
Months")

ggplot(MLSRA_BW, aes(x=BWGrams, y=piat_1st_age))+
  geom_point()+
  geom_smooth()+
```

```
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Peabody Individual Achievement
Test")+
  ggtitle("Birth Weight and Cognitive Functioning in 1st
Grade")

ggplot(MLSRA_BW, aes(x=BWGrams, y=piat_2nd_age))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Peabody Individual Achievement
Test")+
  ggtitle("Birth Weight and Cognitive Functioning in 2nd
Grade")

ggplot(MLSRA_BW, aes(x=BWGrams, y=piat_3rd_age))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Peabody Individual Achievement
Test")+
  ggtitle("Birth Weight and Cognitive Functioning in 3rd
Grade")

ggplot(MLSRA_BW, aes(x=BWGrams, y=piat_6th_age))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Peabody Individual Achievement
Test")+
  ggtitle("Birth Weight and Cognitive Functioning in 6th
Grade")

ggplot(MLSRA_BW, aes(x=BWGrams, y=wjc_16_age))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Peabody Individual Achievement
Test")+
  ggtitle("Birth Weight and Cognitive Functioning at Age
16")

ggplot(MLSRA_BW, aes(x=BWGrams, y=attain23))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Educational Attainment")+
  ggtitle("Birth Weight and Educational Attainment at Age
23")

ggplot(MLSRA_BW, aes(x=BWGrams, y=attain26))+
  geom_point()+
```

```
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Educational Attainment")+
  ggtitle("Birth Weight and Educational Attainment at Age
27")

ggplot(MLSRA_BW, aes(x=BWGrams, y=attain32))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Educational Attainment")+
  ggtitle("Birth Weight and Educational Attainment at Age
32")

ggplot(MLSRA_BW, aes(x=BWGrams, y=attain34))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Educational Attainment")+
  ggtitle("Birth Weight and Educational Attainment at Age
34")
```

Appendix B:
Analysis Script for Social Competence Descriptive Statistics

```
library(readr)
library(Hmisc)
library(ggplot2)

MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)

describe(MLSRA_BW$peer_k)
hist(MLSRA_BW$peer_k)
describe(MLSRA_BW$peer_1)
hist(MLSRA_BW$peer_1)
describe(MLSRA_BW$peer_2)
hist(MLSRA_BW$peer_2)
describe(MLSRA_BW$peer_3)
hist(MLSRA_BW$peer_3)
describe(MLSRA_BW$peer_6)
hist(MLSRA_BW$peer_6)
describe(MLSRA_BW$peer_16)
hist(MLSRA_BW$peer_16)
describe(MLSRA_BW$Rel23Engage)
hist(MLSRA_BW$Rel23Engage)
describe(MLSRA_BW$Rel32Engage)
hist(MLSRA_BW$Rel32Engage)


Soc.mat=as.matrix(MLSRA_BW
                  [,c("BWGrams",
                      "GestAgeBirth",
                      "peer_k",
                      "peer_1",
                      "peer_2",
                      "peer_3",
                      "peer_6",
                      "peer_16",
                      "Rel23Engage",
                      "Rel32Engage")])

rcorr(Soc.mat)
Soc.cor=rcorr(Soc.mat)

Soc.cog=as.matrix(MLSRA_BW
                  [,c("sex",
                      "race",
                      "ses_prn",
                      "mat_edu_prn",
                      "peer_k",
                      "peer_1",
```

```
                      "peer_2",
                      "peer_3",
                      "peer_6",
                      "peer_16",
                      "Rel23Engage",
                      "Rel32Engage")])

rcorr(Soc.cog)


BW.Soc.r=c(Soc.cor$r[1,3:10])
as.matrix(BW.Soc.r)
GA.Soc.r=c(Soc.cor$r[2,3:10])
as.matrix(GA.Soc.r)

plot(x = BW.Soc.r,
     xlab= "Assessment",
     ylab = "Correlation with Birth Weight")

plot(x = GA.Soc.r,
     xlab= "Assessment",
     ylab = "Correlation with Gestational Age")

ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_k))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence In
Kindergarten")

ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_1))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence in Grade 1")

ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_2))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence in Grade 2")

ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_3))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence in Grade 3")
```

```
ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_6))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence in Grade 6")

ggplot(MLSRA_BW, aes(x=BWGrams, y=peer_16))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Teacher-Rated Peer Competence")+
  ggtitle("Birth Weight and Social Competence at Age 16")

ggplot(MLSRA_BW, aes(x=BWGrams, y=Rel23Engage))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Observer-Rated Romantic Competence")+
  ggtitle("Birth Weight and Social Competence at Age 23")

ggplot(MLSRA_BW, aes(x=BWGrams, y=Rel32Engage))+
  geom_point()+
  geom_smooth()+
  scale_x_continuous("Birth Weight in Grams")+
  scale_y_continuous("Observer-Rated Romantic Competence")+
  ggtitle("Birth Weight and Social Competence at Age 32")
```

Appendix C:

Analysis Script for Cognitive Functioning Predicted From Birth Weight

```
# Load Packages ----------------------------------------
library(readr)
library(lavaan)
library(Hmisc)

# import MLSRA data ------------------------------------

MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)

# Scale Birthweight ------------------------------------
MLSRA_BW$BWGrams_z = scale(MLSRA_BW$BWGrams)
hist(MLSRA_BW$BWGrams_z)

MLSRA_BW$GestAgeBirth

MLSRA_BW$GestAgeBirth_z = scale(MLSRA_BW$GestAgeBirth)
hist(MLSRA_BW$GestAgeBirth_z)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)

# Scale Cognitive Variables  ------------------------------
MLSRA_BW$bayleyindex24_z = scale(MLSRA_BW$bayleyindex24)
MLSRA_BW$zimmerman_language42_z =
scale(MLSRA_BW$zimmerman_language42)
MLSRA_BW$wppsi_total64_z = scale(MLSRA_BW$wppsi_total64)
MLSRA_BW$piat_1st_age_z = scale(MLSRA_BW$piat_1st_age)
MLSRA_BW$piat_2nd_age_z = scale(MLSRA_BW$piat_2nd_age)
MLSRA_BW$piat_3rd_age_z = scale(MLSRA_BW$piat_3rd_age)
MLSRA_BW$piat_6th_age_z = scale(MLSRA_BW$piat_6th_age)
MLSRA_BW$wjc_16_age_z = scale(MLSRA_BW$wjc_16_age)
MLSRA_BW$attain23_z = scale(MLSRA_BW$attain23)
MLSRA_BW$attain26_z = scale(MLSRA_BW$attain26)
MLSRA_BW$attain32_z = scale(MLSRA_BW$attain32)
MLSRA_BW$attain34_z = scale(MLSRA_BW$attain34)

# Basic MLSRA EE Cog -----------------------------------

MLSRA_model_cog_ee = '
bayleyindex24_z ~ a*BWGrams_z
zimmerman_language42_z ~ b*BWGrams_z + bayleyindex24_z
```

```
wppsi_total64_z ~ b*BWGrams_z + zimmerman_language42_z
piat_1st_age_z ~ b*BWGrams_z + wppsi_total64_z
piat_2nd_age_z ~ b*BWGrams_z + piat_1st_age_z
piat_3rd_age_z ~ b*BWGrams_z + piat_2nd_age_z
piat_6th_age_z ~ b*BWGrams_z + piat_3rd_age_z
wjc_16_age_z ~ b*BWGrams_z + piat_6th_age_z
attain23_z ~ b*BWGrams_z + wjc_16_age_z
attain26_z ~ b*BWGrams_z + attain23_z
attain32_z ~ b*BWGrams_z + attain26_z
attain34_z ~ b*BWGrams_z + attain32_z
'


# Basic MLSRA Rev Cog ------------------------------------


MLSRA_model_cog_rev = '
bayleyindex24_z ~ a*BWGrams_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z
piat_2nd_age_z ~ 0*BWGrams_z + piat_1st_age_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z
attain23_z ~ 0*BWGrams_z + wjc_16_age_z
attain26_z ~ 0*BWGrams_z + attain23_z
attain32_z ~ 0*BWGrams_z + attain26_z
attain34_z ~ 0*BWGrams_z + attain32_z
'


# Test Basic MLSRA Cog  ----------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_ee = sem(MLSRA_model_cog_ee,
                           data = MLSRA_BW,
                           missing="FIML")
summary(MLSRA_results_cog_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_rev = sem(MLSRA_model_cog_rev,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_cog_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog=anova(MLSRA_results_cog_ee,
                     MLSRA_results_cog_rev)
```

```
MLSRA_test_cog


# EE MLSRA Cog with demo ----------------------------------

MLSRA_model_cog_demo_ee = '
bayleyindex24_z ~ c*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ d*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ d*BWGrams_z + zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_1st_age_z ~ d*BWGrams_z + wppsi_total64_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ d*BWGrams_z + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ d*BWGrams_z + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ d*BWGrams_z + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ d*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
attain23_z ~ d*BWGrams_z + wjc_16_age_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain26_z ~ d*BWGrams_z + attain23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ d*BWGrams_z + attain26_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ d*BWGrams_z + attain32_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'


# Rev MLSRA cog with demo ---------------------------------

MLSRA_model_cog_demo_rev = '
bayleyindex24_z ~ e*BWGrams_z +  z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z +z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ 0*BWGrams_z + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
```

```
attain23_z ~ 0*BWGrams_z + wjc_16_age_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain26_z ~ 0*BWGrams_z + attain23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ 0*BWGrams_z + attain26_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ 0*BWGrams_z + attain32_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'

# Test MLSRA Cog with Demo --------------------------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_demo_ee = sem(MLSRA_model_cog_demo_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_demo_rev = sem(MLSRA_model_cog_demo_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo=anova(MLSRA_results_cog_demo_ee,
                          MLSRA_results_cog_demo_rev)
MLSRA_test_cog_demo


# #EE with Stability Paths  ------------------------------
MLSRA_model_cog_stab_ee = '
bayleyindex24_z ~ e*BWGrams_z
zimmerman_language42_z ~ f*BWGrams_z  + bayleyindex24_z
wppsi_total64_z ~ f*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ f*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z
piat_2nd_age_z ~ f*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ f*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ f*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z
wjc_16_age_z ~ f*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z
attain23_z ~ f*BWGrams_z  + piat_6th_age_z + wjc_16_age_z
attain26_z ~ f*BWGrams_z  + wjc_16_age_z+ attain23_z
```

```
attain32_z ~ f*BWGrams_z  + attain23_z + attain26_z
attain34_z ~ f*BWGrams_z  + attain26_z + attain32_z
'


# #Rev with Stability Paths  -----------------------------

MLSRA_model_cog_stab_rev = '
bayleyindex24_z ~ e*BWGrams_z
zimmerman_language42_z ~ 0*BWGrams_z  + bayleyindex24_z
wppsi_total64_z ~ 0*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ 0*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z
piat_2nd_age_z ~ 0*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ 0*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ 0*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z
attain23_z ~ 0*BWGrams_z  + piat_6th_age_z + wjc_16_age_z
attain26_z ~ 0*BWGrams_z  + wjc_16_age_z+ attain23_z
attain32_z ~ 0*BWGrams_z  + attain23_z + attain26_z
attain34_z ~ 0*BWGrams_z  + attain26_z + attain32_z
'


# Test with stability -------------------------------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_ee = sem(MLSRA_model_cog_stab_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_stab_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_rev = sem(MLSRA_model_cog_stab_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_stab_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_stab=anova(MLSRA_results_cog_stab_ee,
                          MLSRA_results_cog_stab_rev)
MLSRA_test_cog_stab
```

```
# EE with stability and covariates  ----------------------
MLSRA_model_cog_stab_demo_ee = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ f*BWGrams_z  + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ f*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ f*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_2nd_age_z ~ f*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ f*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ f*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ f*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain23_z ~ f*BWGrams_z  + piat_6th_age_z + wjc_16_age_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain26_z ~ f*BWGrams_z  + wjc_16_age_z+ attain23_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ f*BWGrams_z  + attain23_z + attain26_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ f*BWGrams_z  + attain26_z + attain32_z  +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
'


# Rev with Stability and Covarites  ----------------------

MLSRA_model_cog_stab_demo_rev = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*BWGrams_z  + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ 0*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ 0*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
```

```
piat_2nd_age_z ~ 0*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ 0*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ 0*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain23_z ~ 0*BWGrams_z  + piat_6th_age_z + wjc_16_age_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain26_z ~ 0*BWGrams_z  + wjc_16_age_z+ attain23_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ 0*BWGrams_z  + attain23_z + attain26_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ 0*BWGrams_z  + attain26_z + attain32_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
'

# Test model with covariates and stability  ---------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_demo_ee =
sem(MLSRA_model_cog_stab_demo_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_stab_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_demo_rev =
sem(MLSRA_model_cog_stab_demo_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_stab_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo_stab=anova(MLSRA_results_cog_stab_demo_
ee,
                          MLSRA_results_cog_stab_demo_rev)
MLSRA_test_cog_demo_stab


detach(MLSRA_BW)
```

Appendix D:

Analysis Script for Cognitive Functioning Predicted From Gestational Age

```
# Load Packages ----------------------------------------
library(readr)
library(lavaan)
library(Hmisc)


# import MLSRA data --------------------------------------


MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)

# Scale Birthweight ------------------------------------
MLSRA_BW$GestAgeBirth_z = scale(MLSRA_BW$GestAgeBirth)
hist(MLSRA_BW$GestAgeBirth_z, breaks = 10)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)


# Scale Cognitive Variables  ------------------------------
MLSRA_BW$bayleyindex24_z = scale(MLSRA_BW$bayleyindex24)
MLSRA_BW$zimmerman_language42_z =
scale(MLSRA_BW$zimmerman_language42)
MLSRA_BW$wppsi_total64_z = scale(MLSRA_BW$wppsi_total64)
MLSRA_BW$piat_1st_age_z = scale(MLSRA_BW$piat_1st_age)
MLSRA_BW$piat_2nd_age_z = scale(MLSRA_BW$piat_2nd_age)
MLSRA_BW$piat_3rd_age_z = scale(MLSRA_BW$piat_3rd_age)
MLSRA_BW$piat_6th_age_z = scale(MLSRA_BW$piat_6th_age)
MLSRA_BW$wjc_16_age_z = scale(MLSRA_BW$wjc_16_age)
MLSRA_BW$attain23_z = scale(MLSRA_BW$attain23)
MLSRA_BW$attain26_z = scale(MLSRA_BW$attain26)
MLSRA_BW$attain32_z = scale(MLSRA_BW$attain32)
MLSRA_BW$attain34_z = scale(MLSRA_BW$attain34)

# Basic MLSRA EE Cog --------------------------------------

MLSRA_model_cog_ee_ga = '
bayleyindex24_z ~ a*GestAgeBirth_z
zimmerman_language42_z ~ b*GestAgeBirth_z + bayleyindex24_z
wppsi_total64_z ~ b*GestAgeBirth_z + zimmerman_language42_z
piat_1st_age_z ~ b*GestAgeBirth_z + wppsi_total64_z
```

```
piat_2nd_age_z ~ b*GestAgeBirth_z + piat_1st_age_z
piat_3rd_age_z ~ b*GestAgeBirth_z + piat_2nd_age_z
piat_6th_age_z ~ b*GestAgeBirth_z + piat_3rd_age_z
wjc_16_age_z ~ b*GestAgeBirth_z + piat_6th_age_z
attain23_z ~ b*GestAgeBirth_z + wjc_16_age_z
attain26_z ~ b*GestAgeBirth_z + attain23_z
attain32_z ~ b*GestAgeBirth_z + attain26_z
attain34_z ~ b*GestAgeBirth_z + attain32_z
'


# Basic MLSRA Rev Cog ------------------------------------


MLSRA_model_cog_rev_ga = '
bayleyindex24_z ~ a*GestAgeBirth_z
zimmerman_language42_z ~ 0*GestAgeBirth_z + bayleyindex24_z
wppsi_total64_z ~ 0*GestAgeBirth_z + zimmerman_language42_z
piat_1st_age_z ~ 0*GestAgeBirth_z + wppsi_total64_z
piat_2nd_age_z ~ 0*GestAgeBirth_z + piat_1st_age_z
piat_3rd_age_z ~ 0*GestAgeBirth_z + piat_2nd_age_z
piat_6th_age_z ~ 0*GestAgeBirth_z + piat_3rd_age_z
wjc_16_age_z ~ 0*GestAgeBirth_z + piat_6th_age_z
attain23_z ~ 0*GestAgeBirth_z + wjc_16_age_z
attain26_z ~ 0*GestAgeBirth_z + attain23_z
attain32_z ~ 0*GestAgeBirth_z + attain26_z
attain34_z ~ 0*GestAgeBirth_z + attain32_z
'


# Test Basic MLSRA Cog  ----------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_ee_ga = sem(MLSRA_model_cog_ee_ga,
                           data = MLSRA_BW,
                           missing="FIML")
summary(MLSRA_results_cog_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_rev_ga = sem(MLSRA_model_cog_rev_ga,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_cog_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_ga=anova(MLSRA_results_cog_ee_ga,
                     MLSRA_results_cog_rev_ga)
MLSRA_test_cog_ga
```

```
# EE MLSRA Cog with demo ---------------------------------

MLSRA_model_cog_demo_ee_ga = '
bayleyindex24_z ~ c*GestAgeBirth_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ d*GestAgeBirth_z + bayleyindex24_z
+ z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ d*GestAgeBirth_z + zimmerman_language42_z
+ z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_1st_age_z ~ d*GestAgeBirth_z + wppsi_total64_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ d*GestAgeBirth_z + piat_1st_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ d*GestAgeBirth_z + piat_2nd_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ d*GestAgeBirth_z + piat_3rd_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ d*GestAgeBirth_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
attain23_z ~ d*GestAgeBirth_z + wjc_16_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
attain26_z ~ d*GestAgeBirth_z + attain23_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ d*GestAgeBirth_z + attain26_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ d*GestAgeBirth_z + attain32_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
'


# Rev MLSRA cog with demo --------------------------------

MLSRA_model_cog_demo_rev_ga = '
bayleyindex24_z ~ e*GestAgeBirth_z +  z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*GestAgeBirth_z + bayleyindex24_z
+ z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ 0*GestAgeBirth_z + zimmerman_language42_z
+ z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_1st_age_z ~ 0*GestAgeBirth_z + wppsi_total64_z +z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ 0*GestAgeBirth_z + piat_1st_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ 0*GestAgeBirth_z + piat_2nd_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ 0*GestAgeBirth_z + piat_3rd_age_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ 0*GestAgeBirth_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
attain23_z ~ 0*GestAgeBirth_z + wjc_16_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
```

```
attain26_z ~ 0*GestAgeBirth_z + attain23_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ 0*GestAgeBirth_z + attain26_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ 0*GestAgeBirth_z + attain32_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
'


# Test MLSRA Cog with Demo -------------------------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_demo_ee_ga =
sem(MLSRA_model_cog_demo_ee_ga,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_demo_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_demo_rev_ga =
sem(MLSRA_model_cog_demo_rev_ga,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_demo_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo_ga=anova(MLSRA_results_cog_demo_ee_ga,
                          MLSRA_results_cog_demo_rev_ga)
MLSRA_test_cog_demo_ga




# #EE with Stability Paths  ------------------------------
MLSRA_model_cog_stab_ee_ga = '
bayleyindex24_z ~ e*GestAgeBirth_z
zimmerman_language42_z ~ f*GestAgeBirth_z  +
bayleyindex24_z
wppsi_total64_z ~ f*GestAgeBirth_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ f*GestAgeBirth_z  + zimmerman_language42_z
+ wppsi_total64_z
piat_2nd_age_z ~ f*GestAgeBirth_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ f*GestAgeBirth_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ f*GestAgeBirth_z  + piat_2nd_age_z +
piat_3rd_age_z
```

```
wjc_16_age_z ~ f*GestAgeBirth_z  + piat_3rd_age_z +
piat_6th_age_z
attain23_z ~ f*GestAgeBirth_z  + piat_6th_age_z +
wjc_16_age_z
attain26_z ~ f*GestAgeBirth_z  + wjc_16_age_z+ attain23_z
attain32_z ~ f*GestAgeBirth_z  + attain23_z + attain26_z
attain34_z ~ f*GestAgeBirth_z  + attain26_z + attain32_z
'


# #Rev with Stability Paths  ------------------------------

MLSRA_model_cog_stab_rev_ga = '
bayleyindex24_z ~ e*GestAgeBirth_z
zimmerman_language42_z ~ 0*GestAgeBirth_z  +
bayleyindex24_z
wppsi_total64_z ~ 0*GestAgeBirth_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ 0*GestAgeBirth_z  + zimmerman_language42_z
+ wppsi_total64_z
piat_2nd_age_z ~ 0*GestAgeBirth_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ 0*GestAgeBirth_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ 0*GestAgeBirth_z  + piat_2nd_age_z +
piat_3rd_age_z
wjc_16_age_z ~ 0*GestAgeBirth_z  + piat_3rd_age_z +
piat_6th_age_z
attain23_z ~ 0*GestAgeBirth_z  + piat_6th_age_z +
wjc_16_age_z
attain26_z ~ 0*GestAgeBirth_z  + wjc_16_age_z+ attain23_z
attain32_z ~ 0*GestAgeBirth_z  + attain23_z + attain26_z
attain34_z ~ 0*GestAgeBirth_z  + attain26_z + attain32_z
'


# Test with stability -------------------------------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_ee_ga =
sem(MLSRA_model_cog_stab_ee_ga,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_stab_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_rev_ga =
sem(MLSRA_model_cog_stab_rev_ga,
                                 data = MLSRA_BW,
                                 missing="FIML")
```

```
summary(MLSRA_results_cog_stab_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_stab_ga=anova(MLSRA_results_cog_stab_ee_ga,
                          MLSRA_results_cog_stab_rev_ga)
MLSRA_test_cog_stab_ga


# EE with stability and covariates  -----------------------
MLSRA_model_cog_stab_demo_ee_ga = '
bayleyindex24_z ~ e*GestAgeBirth_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ f*GestAgeBirth_z  +
bayleyindex24_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wppsi_total64_z ~ f*GestAgeBirth_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ f*GestAgeBirth_z  + zimmerman_language42_z
+ wppsi_total64_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_2nd_age_z ~ f*GestAgeBirth_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ f*GestAgeBirth_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ f*GestAgeBirth_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ f*GestAgeBirth_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain23_z ~ f*GestAgeBirth_z  + piat_6th_age_z +
wjc_16_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain26_z ~ f*GestAgeBirth_z  + wjc_16_age_z+ attain23_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ f*GestAgeBirth_z  + attain23_z + attain26_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ f*GestAgeBirth_z  + attain26_z + attain32_z  +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
'


# Rev with Stability and Covarites  -----------------------


MLSRA_model_cog_stab_demo_rev_ga = '
```

```
bayleyindex24_z ~ e*GestAgeBirth_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*GestAgeBirth_z  +
bayleyindex24_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wppsi_total64_z ~ 0*GestAgeBirth_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ 0*GestAgeBirth_z  + zimmerman_language42_z
+ wppsi_total64_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_2nd_age_z ~ 0*GestAgeBirth_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ 0*GestAgeBirth_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ 0*GestAgeBirth_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ 0*GestAgeBirth_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain23_z ~ 0*GestAgeBirth_z  + piat_6th_age_z +
wjc_16_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
attain26_z ~ 0*GestAgeBirth_z  + wjc_16_age_z+ attain23_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain32_z ~ 0*GestAgeBirth_z  + attain23_z + attain26_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
attain34_z ~ 0*GestAgeBirth_z  + attain26_z + attain32_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
'

# Test model with covariates and stability  ---------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_demo_ee_ga =
sem(MLSRA_model_cog_stab_demo_ee_ga,
                                     data = MLSRA_BW,
                                     missing="FIML")
summary(MLSRA_results_cog_stab_demo_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_demo_rev_ga =
sem(MLSRA_model_cog_stab_demo_rev_ga,
                                      data = MLSRA_BW,
                                      missing="FIML")
summary(MLSRA_results_cog_stab_demo_rev_ga,
        fit.measures=TRUE,
```

```
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo_stab_ga=anova(MLSRA_results_cog_stab_de
mo_ee_ga,

MLSRA_results_cog_stab_demo_rev_ga)
MLSRA_test_cog_demo_stab_ga


detach(MLSRA_BW)
```

Appendix E:

Analysis Script for Social Competence Predicted From Birth Weight

```
library(readr)
library(lavaan)


# import MLSRA Data data ----------------------------------


MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)


# standardize predictors ----------------------------------

MLSRA_BW$BWGrams_z = scale(MLSRA_BW$BWGrams)
hist(MLSRA_BW$BWGrams_z)
hist(MLSRA_BW$BWGrams,
     main = "Birth Weight",
     xlab = "Birth Weight in Grams",
     breaks = 12)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)


# Scale Variables -----------------------------------------

MLSRA_BW$peerk_z = scale(MLSRA_BW$peer_k)
MLSRA_BW$peer1_z = scale(MLSRA_BW$peer_1)
MLSRA_BW$peer2_z = scale(MLSRA_BW$peer_2)
MLSRA_BW$peer3_z = scale(MLSRA_BW$peer_3)
MLSRA_BW$peer6_z = scale(MLSRA_BW$peer_6)
MLSRA_BW$peer16_z = scale(MLSRA_BW$peer_16)
MLSRA_BW$Rel23_z = scale(MLSRA_BW$Rel23Engage)
MLSRA_BW$Rel32_z = scale(MLSRA_BW$Rel32Engage)


# Basic EE Social MLSRA-----------------------------------

MLSRA_model_soc_ee = '
peerk_z ~ a*BWGrams_z
peer1_z ~ b*BWGrams_z + peerk_z
peer2_z ~ b*BWGrams_z + peer1_z
peer3_z ~ b*BWGrams_z + peer2_z
```

```
peer6_z ~ b*BWGrams_z + peer3_z
peer16_z ~ b*BWGrams_z + peer6_z
Rel23_z ~ b*BWGrams_z + peer16_z
Rel32_z ~ b*BWGrams_z + Rel23_z
'


# Basic Rev Social MLSRA-----------------------------------

MLSRA_model_soc_rev = '
peerk_z ~ a*BWGrams_z
peer1_z ~ 0*BWGrams_z + peerk_z
peer2_z ~ 0*BWGrams_z + peer1_z
peer3_z ~ 0*BWGrams_z + peer2_z
peer6_z ~ 0*BWGrams_z + peer3_z
peer16_z ~ 0*BWGrams_z + peer6_z
Rel23_z ~ 0*BWGrams_z + peer16_z
Rel32_z ~ 0*BWGrams_z + Rel23_z
'

# Test Basic Social Model MLSRA ---------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_ee = sem(MLSRA_model_soc_ee,
                           data = MLSRA_BW,
                           missing="FIML")
summary(MLSRA_results_soc_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_rev = sem(MLSRA_model_soc_rev,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_soc_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_soc=anova(MLSRA_results_soc_ee,
                     MLSRA_results_soc_rev)
MLSRA_test_soc

# EE Social with demo MLSRA--------------------------------

MLSRA_model_soc_demo_ee = '
peerk_z ~ a*BWGrams_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ b*BWGrams_z + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ b*BWGrams_z + peer1_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
```

```
peer3_z ~ b*BWGrams_z + peer2_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ b*BWGrams_z + peer3_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ b*BWGrams_z + peer6_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ b*BWGrams_z + peer16_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ b*BWGrams_z + Rel23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'

# Rev Social with demo MLSRA------------------------------

MLSRA_model_soc_demo_rev = '
peerk_z ~ a*BWGrams_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ 0*BWGrams_z + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ 0*BWGrams_z + peer1_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ 0*BWGrams_z + peer2_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ 0*BWGrams_z + peer3_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ 0*BWGrams_z + peer6_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ 0*BWGrams_z + peer16_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ 0*BWGrams_z + Rel23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'

# Test Social Model MLSRA with demo -----------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_demo_ee = sem(MLSRA_model_soc_demo_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_soc_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_demo_rev = sem(MLSRA_model_soc_demo_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_soc_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
```

```
MLSRA_test_soc_demo=anova(MLSRA_results_soc_demo_ee,
                          MLSRA_results_soc_demo_rev)
MLSRA_test_soc_demo

#Basic EE with stability paths MLSRA-----------------------

MLSRA_model_soc_stab_ee = '
peerk_z ~ d*BWGrams_z
peer1_z ~ e*BWGrams_z  + peerk_z
peer2_z ~ e*BWGrams_z  + peerk_z + peer1_z
peer3_z ~ e*BWGrams_z  + peer1_z + peer2_z
peer6_z ~ e*BWGrams_z  + peer2_z + peer3_z
peer16_z ~ e*BWGrams_z  + peer3_z + peer6_z
Rel23_z ~ e*BWGrams_z  + peer6_z + peer16_z
Rel32_z ~ e*BWGrams_z  + peer16_z + Rel23_z
'


# Basic Rev Social MLSRA-----------------------------------

MLSRA_model_soc_stab_rev = '
peerk_z ~ f*BWGrams_z
peer1_z ~ 0*BWGrams_z  + peerk_z
peer2_z ~ 0*BWGrams_z  + peerk_z + peer1_z
peer3_z ~ 0*BWGrams_z  + peer1_z + peer2_z
peer6_z ~ 0*BWGrams_z  + peer2_z + peer3_z
peer16_z ~ 0*BWGrams_z  + peer3_z + peer6_z
Rel23_z ~ 0*BWGrams_z  + peer6_z + peer16_z
Rel32_z ~ 0*BWGrams_z  + peer16_z + Rel23_z
'

# Test Basic Social Model MLSRA ---------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_stab_ee = sem(MLSRA_model_soc_stab_ee,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_soc_stab_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_stab_rev = sem(MLSRA_model_soc_stab_rev,
                             data = MLSRA_BW,
                             missing="FIML")
summary(MLSRA_results_soc_stab_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_stab_soc=anova(MLSRA_results_soc_stab_ee,
                     MLSRA_results_soc_stab_rev)
```

```
MLSRA_test_stab_soc

#Basic EE with stability paths MLSRA-----------------------

MLSRA_model_soc_stab_demo_ee = '
peerk_z ~ d*BWGrams_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ e*BWGrams_z  + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ e*BWGrams_z  + peerk_z + peer1_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ e*BWGrams_z  + peer1_z + peer2_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ e*BWGrams_z  + peer2_z + peer3_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ e*BWGrams_z  + peer3_z + peer6_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ e*BWGrams_z  + peer6_z + peer16_z+ z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ e*BWGrams_z  + peer16_z + Rel23_z+ z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
'


# Basic Rev Social MLSRA-----------------------------------

MLSRA_model_soc_stab_demo_rev = '
peerk_z ~ f*BWGrams_z  + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ 0*BWGrams_z  + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ 0*BWGrams_z  + peerk_z + peer1_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ 0*BWGrams_z  + peer1_z + peer2_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ 0*BWGrams_z  + peer2_z + peer3_z + z*sex + y*race
+ x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ 0*BWGrams_z  + peer3_z + peer6_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ 0*BWGrams_z  + peer6_z + peer16_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ 0*BWGrams_z  + peer16_z + Rel23_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
'

# Test Basic Social Model MLSRA ----------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_stab_demo_ee =
sem(MLSRA_model_soc_stab_demo_ee,
                                data = MLSRA_BW,
                                missing="FIML")
```

```
summary(MLSRA_results_soc_stab_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_stab_demo_rev =
sem(MLSRA_model_soc_stab_demo_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_soc_stab_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_stab_demo_soc=anova(MLSRA_results_soc_stab_demo_
ee,
                          MLSRA_results_soc_stab_demo_rev)
MLSRA_test_stab_demo_soc


detach(MLSRA_BW)
```

Appendix F:
Analysis Script for Social Competence Predicted From Gestational Age

```
library(readr)
library(lavaan)


# import MLSRA Data data ----------------------------------


MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWData/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)


# standardize predictors ----------------------------------

MLSRA_BW$GestAgeBirth_z = scale(MLSRA_BW$GestAgeBirth)
hist(MLSRA_BW$GestAgeBirth_z)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)


# Scale Variables -----------------------------------------

MLSRA_BW$peerk_z = scale(MLSRA_BW$peer_k)
MLSRA_BW$peer1_z = scale(MLSRA_BW$peer_1)
MLSRA_BW$peer2_z = scale(MLSRA_BW$peer_2)
MLSRA_BW$peer3_z = scale(MLSRA_BW$peer_3)
MLSRA_BW$peer6_z = scale(MLSRA_BW$peer_6)
MLSRA_BW$peer16_z = scale(MLSRA_BW$peer_16)
MLSRA_BW$Rel23_z = scale(MLSRA_BW$Rel23Engage)
MLSRA_BW$Rel32_z = scale(MLSRA_BW$Rel32Engage)


# Basic EE Social MLSRA------------------------------------

MLSRA_model_soc_ee_ga = '
peerk_z ~ a*GestAgeBirth_z
peer1_z ~ b*GestAgeBirth_z + peerk_z
peer2_z ~ b*GestAgeBirth_z + peer1_z
peer3_z ~ b*GestAgeBirth_z + peer2_z
peer6_z ~ b*GestAgeBirth_z + peer3_z
peer16_z ~ b*GestAgeBirth_z + peer6_z
Rel23_z ~ b*GestAgeBirth_z + peer16_z
Rel32_z ~ b*GestAgeBirth_z + Rel23_z
```

```
'


# Basic Rev Social MLSRA---------------------------------

MLSRA_model_soc_rev_ga = '
peerk_z ~ a*GestAgeBirth_z
peer1_z ~ 0*GestAgeBirth_z + peerk_z
peer2_z ~ 0*GestAgeBirth_z + peer1_z
peer3_z ~ 0*GestAgeBirth_z + peer2_z
peer6_z ~ 0*GestAgeBirth_z + peer3_z
peer16_z ~ 0*GestAgeBirth_z + peer6_z
Rel23_z ~ 0*GestAgeBirth_z + peer16_z
Rel32_z ~ 0*GestAgeBirth_z + Rel23_z
'

# Test Basic Social Model MLSRA ---------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_ee_ga = sem(MLSRA_model_soc_ee_ga,
                           data = MLSRA_BW,
                           missing="FIML")
summary(MLSRA_results_soc_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_rev_ga = sem(MLSRA_model_soc_rev_ga,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_soc_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_soc_ga=anova(MLSRA_results_soc_ee_ga,
                     MLSRA_results_soc_rev_ga)
MLSRA_test_soc_ga

# EE Social with demo MLSRA-------------------------------

MLSRA_model_soc_demo_ee_ga = '
peerk_z ~ a*GestAgeBirth_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ b*GestAgeBirth_z + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ b*GestAgeBirth_z + peer1_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ b*GestAgeBirth_z + peer2_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ b*GestAgeBirth_z + peer3_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
```

```
peer16_z ~ b*GestAgeBirth_z + peer6_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ b*GestAgeBirth_z + peer16_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ b*GestAgeBirth_z + Rel23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'

# Rev Social with demo MLSRA-------------------------------

MLSRA_model_soc_demo_rev_ga = '
peerk_z ~ a*GestAgeBirth_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ 0*GestAgeBirth_z + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ 0*GestAgeBirth_z + peer1_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ 0*GestAgeBirth_z + peer2_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ 0*GestAgeBirth_z + peer3_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ 0*GestAgeBirth_z + peer6_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ 0*GestAgeBirth_z + peer16_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ 0*GestAgeBirth_z + Rel23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
'

# Test Social Model MLSRA with demo -----------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_demo_ee_ga =
sem(MLSRA_model_soc_demo_ee_ga,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_soc_demo_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_demo_rev_ga =
sem(MLSRA_model_soc_demo_rev_ga,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_soc_demo_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_soc_demo_ga=anova(MLSRA_results_soc_demo_ee_ga,
                          MLSRA_results_soc_demo_rev_ga)
```

```
MLSRA_test_soc_demo_ga

#Basic EE with stability paths MLSRA-----------------------

MLSRA_model_soc_stab_ee_ga = '
peerk_z ~ d*GestAgeBirth_z
peer1_z ~ e*GestAgeBirth_z  + peerk_z
peer2_z ~ e*GestAgeBirth_z  + peerk_z + peer1_z
peer3_z ~ e*GestAgeBirth_z  + peer1_z + peer2_z
peer6_z ~ e*GestAgeBirth_z  + peer2_z + peer3_z
peer16_z ~ e*GestAgeBirth_z  + peer3_z + peer6_z
Rel23_z ~ e*GestAgeBirth_z  + peer6_z + peer16_z
Rel32_z ~ e*GestAgeBirth_z  + peer16_z + Rel23_z
'


# Basic Rev Social MLSRA-----------------------------------

MLSRA_model_soc_stab_rev_ga = '
peerk_z ~ f*GestAgeBirth_z
peer1_z ~ 0*GestAgeBirth_z  + peerk_z
peer2_z ~ 0*GestAgeBirth_z  + peerk_z + peer1_z
peer3_z ~ 0*GestAgeBirth_z  + peer1_z + peer2_z
peer6_z ~ 0*GestAgeBirth_z  + peer2_z + peer3_z
peer16_z ~ 0*GestAgeBirth_z  + peer3_z + peer6_z
Rel23_z ~ 0*GestAgeBirth_z  + peer6_z + peer16_z
Rel32_z ~ 0*GestAgeBirth_z  + peer16_z + Rel23_z
'

# Test Basic Social Model MLSRA ---------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_stab_ee_ga =
sem(MLSRA_model_soc_stab_ee_ga,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_soc_stab_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_stab_rev_ga =
sem(MLSRA_model_soc_stab_rev_ga,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_soc_stab_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_stab_soc_ga=anova(MLSRA_results_soc_stab_ee_ga,
                          MLSRA_results_soc_stab_rev_ga)
```

```
MLSRA_test_stab_soc_ga

#Basic EE with stability paths MLSRA----------------------

MLSRA_model_soc_stab_demo_ee_ga = '
peerk_z ~ d*GestAgeBirth_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
peer1_z ~ e*GestAgeBirth_z  + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ e*GestAgeBirth_z  + peerk_z + peer1_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ e*GestAgeBirth_z  + peer1_z + peer2_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ e*GestAgeBirth_z  + peer2_z + peer3_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ e*GestAgeBirth_z  + peer3_z + peer6_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ e*GestAgeBirth_z  + peer6_z + peer16_z+ z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ e*GestAgeBirth_z  + peer16_z + Rel23_z+ z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
'


# Basic Rev Social MLSRA----------------------------------

MLSRA_model_soc_stab_demo_rev_ga = '
peerk_z ~ f*GestAgeBirth_z  + z*sex + y*race + x*ses_prn_z
+ w*mat_edu_prn_z
peer1_z ~ 0*GestAgeBirth_z  + peerk_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
peer2_z ~ 0*GestAgeBirth_z  + peerk_z + peer1_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer3_z ~ 0*GestAgeBirth_z  + peer1_z + peer2_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer6_z ~ 0*GestAgeBirth_z  + peer2_z + peer3_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
peer16_z ~ 0*GestAgeBirth_z  + peer3_z + peer6_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel23_z ~ 0*GestAgeBirth_z  + peer6_z + peer16_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
Rel32_z ~ 0*GestAgeBirth_z  + peer16_z + Rel23_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
'

# Test Basic Social Model MLSRA --------------------------

# Estimate parameters of EE Cog model
MLSRA_results_soc_stab_demo_ee_ga =
sem(MLSRA_model_soc_stab_demo_ee_ga,
                                     data = MLSRA_BW,
                                     missing="FIML")
```

```
summary(MLSRA_results_soc_stab_demo_ee_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_soc_stab_demo_rev_ga =
sem(MLSRA_model_soc_stab_demo_rev_ga,
                                      data = MLSRA_BW,
                                      missing="FIML")
summary(MLSRA_results_soc_stab_demo_rev_ga,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_stab_demo_soc_ga=anova(MLSRA_results_soc_stab_de
mo_ee_ga,

MLSRA_results_soc_stab_demo_rev_ga)
MLSRA_test_stab_demo_soc_ga



detach(MLSRA_BW)
```

Appendix G:

Analysis Script for Cognitive Functioning Predicted From Birth Weight Truncated to 16 Years

```
# Load Packages ----------------------------------------
library(readr)
library(lavaan)
library(Hmisc)


# import MLSRA data ------------------------------------


MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)

# Scale Birthweight ------------------------------------
MLSRA_BW$BWGrams_z = scale(MLSRA_BW$BWGrams)
hist(MLSRA_BW$BWGrams_z)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)

# Scale Cognitive Variables  ---------------------------
MLSRA_BW$bayleyindex24_z = scale(MLSRA_BW$bayleyindex24)
MLSRA_BW$zimmerman_language42_z =
scale(MLSRA_BW$zimmerman_language42)
MLSRA_BW$wppsi_total64_z = scale(MLSRA_BW$wppsi_total64)
MLSRA_BW$piat_1st_age_z = scale(MLSRA_BW$piat_1st_age)
MLSRA_BW$piat_2nd_age_z = scale(MLSRA_BW$piat_2nd_age)
MLSRA_BW$piat_3rd_age_z = scale(MLSRA_BW$piat_3rd_age)
MLSRA_BW$piat_6th_age_z = scale(MLSRA_BW$piat_6th_age)
MLSRA_BW$wjc_16_age_z = scale(MLSRA_BW$wjc_16_age)

# Basic MLSRA EE Cog -----------------------------------

MLSRA_model_cog_ee = '
bayleyindex24_z ~ a*BWGrams_z
zimmerman_language42_z ~ b*BWGrams_z + bayleyindex24_z
wppsi_total64_z ~ b*BWGrams_z + zimmerman_language42_z
piat_1st_age_z ~ b*BWGrams_z + wppsi_total64_z
piat_2nd_age_z ~ b*BWGrams_z + piat_1st_age_z
piat_3rd_age_z ~ b*BWGrams_z + piat_2nd_age_z
piat_6th_age_z ~ b*BWGrams_z + piat_3rd_age_z
```

```
wjc_16_age_z ~ b*BWGrams_z + piat_6th_age_z
'


# Basic MLSRA Rev Cog ------------------------------------


MLSRA_model_cog_rev = '
bayleyindex24_z ~ a*BWGrams_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z
piat_2nd_age_z ~ 0*BWGrams_z + piat_1st_age_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z
'


# Test Basic MLSRA Cog  ----------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_ee = sem(MLSRA_model_cog_ee,
                           data = MLSRA_BW,
                           missing="FIML")
summary(MLSRA_results_cog_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_rev = sem(MLSRA_model_cog_rev,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_cog_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog=anova(MLSRA_results_cog_ee,
                     MLSRA_results_cog_rev)
MLSRA_test_cog


# EE MLSRA Cog with demo ---------------------------------

MLSRA_model_cog_demo_ee = '
bayleyindex24_z ~ c*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ d*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ d*BWGrams_z + zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
```

```
piat_1st_age_z ~ d*BWGrams_z + wppsi_total64_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ d*BWGrams_z + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ d*BWGrams_z + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ d*BWGrams_z + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ d*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
'


# Rev MLSRA cog with demo --------------------------------

MLSRA_model_cog_demo_rev = '
bayleyindex24_z ~ e*BWGrams_z +  z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z +z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_2nd_age_z ~ 0*BWGrams_z + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z
'


# Test MLSRA Cog with Demo --------------------------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_demo_ee = sem(MLSRA_model_cog_demo_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_demo_rev = sem(MLSRA_model_cog_demo_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)
```

```
# Compare the two models
MLSRA_test_cog_demo=anova(MLSRA_results_cog_demo_ee,
                          MLSRA_results_cog_demo_rev)
MLSRA_test_cog_demo



# #EE with Stability Paths  --------------------------------
MLSRA_model_cog_stab_ee = '
bayleyindex24_z ~ e*BWGrams_z
zimmerman_language42_z ~ f*BWGrams_z  + bayleyindex24_z
wppsi_total64_z ~ f*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ f*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z
piat_2nd_age_z ~ f*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ f*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ f*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z
wjc_16_age_z ~ f*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z
'


# #Rev with Stability Paths  --------------------------------


MLSRA_model_cog_stab_rev = '
bayleyindex24_z ~ e*BWGrams_z
zimmerman_language42_z ~ 0*BWGrams_z  + bayleyindex24_z
wppsi_total64_z ~ 0*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z
piat_1st_age_z ~ 0*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z
piat_2nd_age_z ~ 0*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z
piat_3rd_age_z ~ 0*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z
piat_6th_age_z ~ 0*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z
'


# Test with stability --------------------------------------
```

```
# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_ee = sem(MLSRA_model_cog_stab_ee,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_stab_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_rev = sem(MLSRA_model_cog_stab_rev,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_stab_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_stab=anova(MLSRA_results_cog_stab_ee,
                          MLSRA_results_cog_stab_rev)
MLSRA_test_cog_stab



# EE with stability and covariates  -----------------------
MLSRA_model_cog_stab_demo_ee = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ f*BWGrams_z  + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ f*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ f*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_2nd_age_z ~ f*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ f*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ f*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ f*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
'


# Rev with Stability and Covarites  -----------------------
MLSRA_model_cog_stab_demo_rev = '
```

```
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z
zimmerman_language42_z ~ 0*BWGrams_z  + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z
wppsi_total64_z ~ 0*BWGrams_z  + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_1st_age_z ~ 0*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_2nd_age_z ~ 0*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_3rd_age_z ~ 0*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
piat_6th_age_z ~ 0*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z
'

# Test model with covariates and stability  ---------------

# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_demo_ee =
sem(MLSRA_model_cog_stab_demo_ee,
                                     data = MLSRA_BW,
                                     missing="FIML")
summary(MLSRA_results_cog_stab_demo_ee,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_demo_rev =
sem(MLSRA_model_cog_stab_demo_rev,
                                      data = MLSRA_BW,
                                      missing="FIML")
summary(MLSRA_results_cog_stab_demo_rev,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo_stab=anova(MLSRA_results_cog_stab_demo_
ee,

MLSRA_results_cog_stab_demo_rev)
MLSRA_test_cog_demo_stab
```

```
detach(MLSRA_BW)
```

Appendix H:

Analysis Script for Cognitive Functioning Predicted by Birth Weight Controlling for Gestational Age

```
# Load Packages ----------------------------------------
library(readr)
library(lavaan)
library(Hmisc)
library(ggplot2)
library(lm.beta)


# import MLSRA data ------------------------------------
MLSRA_BW <-
read_csv("~/Dropbox/Psychology/Dissertation/Data/MLSRA/BWDa
ta/BirthWeightDataMLSRA.csv")
View(MLSRA_BW)
attach(MLSRA_BW)

MLSRA_BW$BWGrams_z = scale(MLSRA_BW$BWGrams)
hist(MLSRA_BW$BWGrams_z)

MLSRA_BW$GestAgeBirth

MLSRA_BW$GestAgeBirth_z = scale(MLSRA_BW$GestAgeBirth)
hist(MLSRA_BW$GestAgeBirth_z)

MLSRA_BW$mat_edu_prn_z = scale(MLSRA_BW$mat_edu_prn)
hist(MLSRA_BW$mat_edu_prn_z)

MLSRA_BW$ses_prn_z=scale(MLSRA_BW$ses_prn)
hist(MLSRA_BW$ses_prn_z)

# Scale Cognitive Variables  ------------------------------
MLSRA_BW$bayleyindex24_z = scale(MLSRA_BW$bayleyindex24)
MLSRA_BW$zimmerman_language42_z =
scale(MLSRA_BW$zimmerman_language42)
MLSRA_BW$wppsi_total64_z = scale(MLSRA_BW$wppsi_total64)
MLSRA_BW$piat_1st_age_z = scale(MLSRA_BW$piat_1st_age)
MLSRA_BW$piat_2nd_age_z = scale(MLSRA_BW$piat_2nd_age)
MLSRA_BW$piat_3rd_age_z = scale(MLSRA_BW$piat_3rd_age)
MLSRA_BW$piat_6th_age_z = scale(MLSRA_BW$piat_6th_age)
MLSRA_BW$wjc_16_age_z = scale(MLSRA_BW$wjc_16_age)
MLSRA_BW$attain23_z = scale(MLSRA_BW$attain23)
MLSRA_BW$attain26_z = scale(MLSRA_BW$attain26)
MLSRA_BW$attain32_z = scale(MLSRA_BW$attain32)
MLSRA_BW$attain34_z = scale(MLSRA_BW$attain34)

# Basic MLSRA EE Cog ------------------------------------

MLSRA_model_cog_ee_both = '
```

```
bayleyindex24_z ~ a*BWGrams_z + q*GestAgeBirth_z
zimmerman_language42_z ~ b*BWGrams_z + bayleyindex24_z +
q*GestAgeBirth_z
wppsi_total64_z ~ b*BWGrams_z + zimmerman_language42_z +
q*GestAgeBirth_z
piat_1st_age_z ~ b*BWGrams_z + wppsi_total64_z +q*
GestAgeBirth_z
piat_2nd_age_z ~ b*BWGrams_z + piat_1st_age_z +
q*GestAgeBirth_z
piat_3rd_age_z ~ b*BWGrams_z + piat_2nd_age_z +
q*GestAgeBirth_z
piat_6th_age_z ~ b*BWGrams_z + piat_3rd_age_z +
q*GestAgeBirth_z
wjc_16_age_z ~ b*BWGrams_z + piat_6th_age_z +
q*GestAgeBirth_z
attain23_z ~ b*BWGrams_z + wjc_16_age_z + q*GestAgeBirth_z
attain26_z ~ b*BWGrams_z + attain23_z + q*GestAgeBirth_z
attain32_z ~ b*BWGrams_z + attain26_z + q*GestAgeBirth_z
attain34_z ~ b*BWGrams_z + attain32_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Basic MLSRA Rev Cog -------------------------------------


MLSRA_model_cog_rev_both = '
bayleyindex24_z ~ a*BWGrams_z + q*GestAgeBirth_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z +
q*GestAgeBirth_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z +
q*GestAgeBirth_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z +
q*GestAgeBirth_z
piat_2nd_age_z ~ 0*BWGrams_z + piat_1st_age_z +
q*GestAgeBirth_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z +
q*GestAgeBirth_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z +
q*GestAgeBirth_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z +
q*GestAgeBirth_z
attain23_z ~ 0*BWGrams_z + wjc_16_age_z + q*GestAgeBirth_z
attain26_z ~ 0*BWGrams_z + attain23_z + q*GestAgeBirth_z
attain32_z ~ 0*BWGrams_z + attain26_z + q*GestAgeBirth_z
attain34_z ~ 0*BWGrams_z + attain32_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Test Basic MLSRA Cog  -----------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_ee_both = sem(MLSRA_model_cog_ee_both,
                           data = MLSRA_BW,
```

```
                           missing="FIML")
summary(MLSRA_results_cog_ee_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_rev_both = sem(MLSRA_model_cog_rev_both,
                            data = MLSRA_BW,
                            missing="FIML")
summary(MLSRA_results_cog_rev_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_both=anova(MLSRA_results_cog_ee_both,
                     MLSRA_results_cog_rev_both)
MLSRA_test_cog_both


# EE MLSRA Cog with demo ----------------------------------
MLSRA_model_cog_demo_ee_both = '
bayleyindex24_z ~ c*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
zimmerman_language42_z ~ d*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
wppsi_total64_z ~ d*BWGrams_z +zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
piat_1st_age_z ~ d*BWGrams_z + wppsi_total64_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_2nd_age_z ~ d*BWGrams_z + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_3rd_age_z ~ d*BWGrams_z  + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_6th_age_z ~ d*BWGrams_z  + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
wjc_16_age_z ~ d*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain23_z ~ d*BWGrams_z  + wjc_16_age_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain26_z ~ d*BWGrams_z  + attain23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain32_z ~ d*BWGrams_z + attain26_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain34_z ~ d*BWGrams_z + attain32_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'
```

```
# Rev MLSRA cog with demo --------------------------------
MLSRA_model_cog_demo_rev_both = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
wppsi_total64_z ~ 0*BWGrams_z + zimmerman_language42_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
piat_1st_age_z ~ 0*BWGrams_z + wppsi_total64_z +z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_2nd_age_z ~ 0*BWGrams_z  + piat_1st_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_2nd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
piat_6th_age_z ~ 0*BWGrams_z + piat_3rd_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
wjc_16_age_z ~ 0*BWGrams_z + piat_6th_age_z + z*sex +
y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain23_z ~ 0*BWGrams_z + wjc_16_age_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain26_z ~ 0*BWGrams_z + attain23_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain32_z ~ 0*BWGrams_z + attain26_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain34_z ~ 0*BWGrams_z + attain32_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Test MLSRA Cog with Demo --------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_demo_ee_both =
sem(MLSRA_model_cog_demo_ee_both,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_demo_ee_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_demo_rev_both =
sem(MLSRA_model_cog_demo_rev_both,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_demo_rev_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
```

```
MLSRA_test_cog_demo_both=anova(MLSRA_results_cog_demo_ee_bo
th,
                          MLSRA_results_cog_demo_rev_both)
MLSRA_test_cog_demo_both


# #EE with Stability Paths  -----------------------------
MLSRA_model_cog_stab_ee_both = '
bayleyindex24_z ~ e*BWGrams_z + q*GestAgeBirth_z
zimmerman_language42_z ~ f*BWGrams_z + GestAgeBirth_z  +
bayleyindex24_z + q*GestAgeBirth_z
wppsi_total64_z ~ f*BWGrams_z + bayleyindex24_z +
zimmerman_language42_z + q*GestAgeBirth_z
piat_1st_age_z ~ f*BWGrams_z + zimmerman_language42_z +
wppsi_total64_z + q*GestAgeBirth_z
piat_2nd_age_z ~ f*BWGrams_z + wppsi_total64_z +
piat_1st_age_z + q*GestAgeBirth_z
piat_3rd_age_z ~ f*BWGrams_z + piat_1st_age_z +
piat_2nd_age_z + q*GestAgeBirth_z
piat_6th_age_z ~ f*BWGrams_z + piat_2nd_age_z +
piat_3rd_age_z + q*GestAgeBirth_z
wjc_16_age_z ~ f*BWGrams_z + piat_3rd_age_z +
piat_6th_age_z + q*GestAgeBirth_z
attain23_z ~ f*BWGrams_z + piat_6th_age_z + wjc_16_age_z +
q*GestAgeBirth_z
attain26_z ~ f*BWGrams_z + wjc_16_age_z+ attain23_z +
q*GestAgeBirth_z
attain32_z ~ f*BWGrams_z + attain23_z + attain26_z +
q*GestAgeBirth_z
attain34_z ~ f*BWGrams_z+ attain26_z + attain32_z +
q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# #Rev with Stability Paths  -----------------------------
MLSRA_model_cog_stab_rev_both = '
bayleyindex24_z ~ e*BWGrams_z + q*GestAgeBirth_z
zimmerman_language42_z ~ 0*BWGrams_z + bayleyindex24_z +
q*GestAgeBirth_z
wppsi_total64_z ~ 0*BWGrams_z + bayleyindex24_z +
zimmerman_language42_z + q*GestAgeBirth_z
piat_1st_age_z ~ 0*BWGrams_z  + zimmerman_language42_z +
wppsi_total64_z + q*GestAgeBirth_z
piat_2nd_age_z ~ 0*BWGrams_z  + wppsi_total64_z +
piat_1st_age_z + q*GestAgeBirth_z
piat_3rd_age_z ~ 0*BWGrams_z  + piat_1st_age_z +
piat_2nd_age_z + q*GestAgeBirth_z
piat_6th_age_z ~ 0*BWGrams_z  + piat_2nd_age_z +
piat_3rd_age_z + q*GestAgeBirth_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + q*GestAgeBirth_z
```

```
attain23_z ~ 0*BWGrams_z + piat_6th_age_z + wjc_16_age_z +
q*GestAgeBirth_z
attain26_z ~ 0*BWGrams_z + wjc_16_age_z+ attain23_z +
q*GestAgeBirth_z
attain32_z ~ 0*BWGrams_z + attain23_z + attain26_z +
q*GestAgeBirth_z
attain34_z ~ 0*BWGrams_z + attain26_z + attain32_z +
q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Test with stability ------------------------------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_ee_both =
sem(MLSRA_model_cog_stab_ee_both,
                                data = MLSRA_BW,
                                missing="FIML")
summary(MLSRA_results_cog_stab_ee_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_rev_both =
sem(MLSRA_model_cog_stab_rev_both,
                                 data = MLSRA_BW,
                                 missing="FIML")
summary(MLSRA_results_cog_stab_rev_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_stab_both=anova(MLSRA_results_cog_stab_ee_bo
th,
                          MLSRA_results_cog_stab_rev_both)
MLSRA_test_cog_stab_both

# EE with stability and covariates  -----------------------
MLSRA_model_cog_stab_demo_ee_both = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z+ q*GestAgeBirth_z
zimmerman_language42_z ~ f*BWGrams_z + bayleyindex24_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z+
q*GestAgeBirth_z
wppsi_total64_z ~ f*BWGrams_z + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_1st_age_z ~ f*BWGrams_z + zimmerman_language42_z +
wppsi_total64_z +z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_2nd_age_z ~ f*BWGrams_z + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
```

```
piat_3rd_age_z ~ f*BWGrams_z + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_6th_age_z ~ f*BWGrams_z + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
wjc_16_age_z ~ f*BWGrams_z + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
attain23_z ~ f*BWGrams_z + piat_6th_age_z + wjc_16_age_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
attain26_z ~ f*BWGrams_z + wjc_16_age_z+ attain23_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain32_z ~ f*BWGrams_z + attain23_z + attain26_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain34_z ~ f*BWGrams_z + attain26_z + attain32_z  + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Rev with Stability and Covarites  ----------------------
MLSRA_model_cog_stab_demo_rev_both = '
bayleyindex24_z ~ e*BWGrams_z + z*sex + y*race +
x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
zimmerman_language42_z ~ 0*BWGrams_z +   + bayleyindex24_z
+ z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
wppsi_total64_z ~ 0*BWGrams_z + bayleyindex24_z +
zimmerman_language42_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_1st_age_z ~ 0*BWGrams_z + zimmerman_language42_z +
wppsi_total64_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_2nd_age_z ~ 0*BWGrams_z + wppsi_total64_z +
piat_1st_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_3rd_age_z ~ 0*BWGrams_z + piat_1st_age_z +
piat_2nd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
piat_6th_age_z ~ 0*BWGrams_z + piat_2nd_age_z +
piat_3rd_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
wjc_16_age_z ~ 0*BWGrams_z  + piat_3rd_age_z +
piat_6th_age_z + z*sex + y*race + x*ses_prn_z +
w*mat_edu_prn_z + q*GestAgeBirth_z
attain23_z ~ 0*BWGrams_z + piat_6th_age_z + wjc_16_age_z +
z*sex + y*race + x*ses_prn_z + w*mat_edu_prn_z +
q*GestAgeBirth_z
attain26_z ~ 0*BWGrams_z + wjc_16_age_z+ attain23_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
```

```
attain32_z ~ 0*BWGrams_z + attain23_z + attain26_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
attain34_z ~ 0*BWGrams_z + attain26_z + attain32_z + z*sex
+ y*race + x*ses_prn_z + w*mat_edu_prn_z + q*GestAgeBirth_z
BWGrams_z ~~ GestAgeBirth_z
'

# Test model with covariates and stability  ---------------
# Estimate parameters of EE Cog model
MLSRA_results_cog_stab_demo_ee_both =
sem(MLSRA_model_cog_stab_demo_ee_both,
                                     data = MLSRA_BW,
                                     missing="FIML")
summary(MLSRA_results_cog_stab_demo_ee_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Estimate parameters of Revisionist Cog model
MLSRA_results_cog_stab_demo_rev_both =
sem(MLSRA_model_cog_stab_demo_rev_both,
                                      data = MLSRA_BW,
                                      missing="FIML")
summary(MLSRA_results_cog_stab_demo_rev_both,
        fit.measures=TRUE,
        standardized=TRUE)

# Compare the two models
MLSRA_test_cog_demo_stab_both=anova(MLSRA_results_cog_stab_
demo_ee_both,

MLSRA_results_cog_stab_demo_rev_both)
MLSRA_test_cog_demo_stab_both

detach(MLSRA_BW)

# regressions ---------------------------------------------
summary(lm(bayleyindex24_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(bayleyindex24_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(zimmerman_language42_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(zimmerman_language42_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(wppsi_total64_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(wppsi_total64_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
```

```
summary(lm(piat_1st_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(piat_1st_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(piat_2nd_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(piat_2nd_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(piat_3rd_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(piat_3rd_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(piat_6th_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(piat_6th_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(wjc_16_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(wjc_16_age_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(attain23_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(attain23_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(attain26_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(attain26_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(attain32_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(attain32_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))

summary(lm(attain34_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
lm.beta(lm(attain34_z~GestAgeBirth_z+BWGrams_z,
data=MLSRA_BW))
```