Using Multilevel Modeling for Change to Assess Early Children's Reading Growth over Time

Xing Liu
Eastern Connecticut State University

Ann A. O'Connell
The Ohio State University

May 15, 2008

Paper presented at the Annual Conference of the Northeastern Educational Research Association
Kerhonkson, NY, October, 2005

Using Multilevel Modeling for Change to Assess Early Children's Reading Growth over Time

Introduction

Childhood is the crucial period for building reading ability. Research founded that early reading experience had a positive and long-term effect on reading competence for high school seniors (Hanson & Farrell, 1995). Their finding suggested that students with good reading ability in early kindergarten tended to be excellent in reading skills as seniors in high school, whether they were disadvantaged students or advantaged students. Kindergarten and the first year of school are the two most important years for children to acquire necessary reading skills and build reading ability, which set the foundations for future reading gain. Denton and West (2002) found that children's reading ability improved considerably by the end of the first Grade: 75% of the students could read often-used words, and 40% of the students could read and understand words in context. The preliminary study of Denton, West and Walston (2003) indicated that some school, classroom, and individual or home factors influencing children's reading skills, such as gender difference, early literacy skills, learning approaches, home environment and child health. Rathbun and Hausken (2003) also found that the frequency of children's exposure to reading activities during the week, and the students' progress in reading were affected by child, family and school characteristics. Therefore, it is of great importance for researchers to understand children's initial reading ability, their growth trajectory over time, and furthermore, the effects of child and family characteristics on the growth trajectories.

The multilevel modeling for change (Singer, 1998; Singer & Willett, 2003) or hierarchical linear modeling (Raudenbush & Bryk, 2002) is a very promising approach for longitudinal data analysis in recent years. It can model within-individual change over time, inter-individual differences in change, and even differences in change among higher level groups. In the current demonstration study, a two-level model for change, with repeated measurements nested within individuals, was used to assess children's reading ability growth during their first two years of schooling. Data from the kindergarten cohort of the Early Childhood Longitudinal Study (ECLS-K) (U. S. Department of Education, 2001, 2002) was used for this study.

Purpose

The purpose of this study was to illustrate the use of multilevel modeling to assess children's early reading growth from their entering kindergarten through the first year in elementary school. The research questions mainly focused on: (1) how each child's reading ability grew over time; (2) how the growth trajectories varied across children; and (3) how child-level variables, such as how often parents read to children, the number of hours children watch TV on weekdays, and whether children received pre-kindergarten daycare were associated with initial status and rate of change of reading ability over time. Reading ability was measured in the ECLS-K using a collection of assessment items for which item-response theory (IRT) was used to scale the scores for comparison purposes (US Department of Education, 2002)

Methods

Sample

The data here was drawn from the Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K) school year, which was conducted by the National Center for Educational Statistics (NCES). Data from the base year (kindergarten) and first year were used, including information for children, their families, teachers, and schools. The full ECLS-K base-year sample was comprised of approximately 22,000 children who attended about 1,000 kindergarten programs during the 1998-99 school year. In the first two years of the ECLS-K study, child-level data was collected at 4 consecutive times: Kindergarten in the fall and again in the spring, and first grade in the fall and in the spring. A subset of children were selected for these analyses: those who attended the same school for kindergarten and first grade, were first-time kindergarteners who were not repeating kindergarten or first grade, who were not second language learners, who were not in special education programs, and who had no missing values on the explanatory variables of interest.

In the data analyses for the present study, the child-level data set was constructed as a person-level data set (a multivariate layout, with one record per child), as well as a person-period data set (multiple records per child, representing each time-point for data collection). The former included the variables of interest, such as childid, schoolid, IRT-scaled reading scores at four consecutive times (c1read, c2read, c3read and c4read), whether or not child attended center-based daycare prior to kindergarten (daycare), how often parents read to children (p1readbo), and the number of hours of watching TV in weekdays (p2numtv). The latter data set-up included variables such as childid, schoolid, reading IRT score, and a time variable, TIMEMOS, measured as 0 (baseline or initial data collection), 8 months, 12 months, and 20 months. Explanatory variables of daycare, p1readbo, and p2numtv were also included in the person-period data set. The person-period data set thus is a composite data set with multiple records, to meet the needs of multilevel data analysis using the SAS program. In the following data analyses, the total number of students was 3534. The number of data collection waves was 4, because the data was collected at 0, 8, 12, and 20 months starting with the beginning of kindergarten until the end of first grade. The outcome variable, READING, was the children's IRT-scaled reading score. ID was the child identification number. TIMEMOS was the time indicator, indicating the increase in age in months since baseline for each child across the four measurement occasions. P1READBO is a time-invariant predictor, indicating how often parents read to their children (frequency with which parents read books to children prior to kindergarten entry, rated as 1 to 4 with 1=never, 4=everyday). P2NUMTV is a time-invariant predictor indicating the number of hours of watching TV on weekdays. DAYCARE was also a time-invariant predictor, indicating whether or not child ever received center-based day-care prior to attending kindergarten (0=no, 1=yes). TIMEMOS was not centered in any of the models presented here because the starting measurement time was 0, which was the starting time when children entered kindergarten. To simply interpretation, P1READBO was centered at its grand mean, 3.31, and P2NUMTV at its grand mean, 1.97, to make the intercepts in the following level-2 models more interpretable. Table 1 displays the descriptive statistics of the child-level variables.

Methods

First, before the multilevel models were fitted, ordinary least squares (OLS) regression was used for exploratory purpose, because it could provide the direct results of the estimated growth trajectory of reading ability for each child over time, and descriptive information about the inter-individual difference among these regressions. We randomly selected 10% of the child-level data set to simplify the descriptive data analyses (the original data set has 3534 students, with 14136 observations over four time periods), therefore, the sub-sample data set had 337 children. In this sub-sample, CREAD was the variable name for the IRT reading score, and MONTH was the time variable. The growth plots for representative children were constructed. Next, the estimated linear growth parameters of initial status (intercept), standard error of initial status, change (slope), the standard error of change, and variance explained were derived, in an effort to assess fit of the regression line for reading ability for each child, and to assess inter-individual differences in the growth of reading ability between children. Although the OLS regression approach is easier to understand for people with limited knowledge of multilevel modeling, it was used primarily for exploratory purposes here.

In the second phase of this demonstration study, a two-level model for change was developed to investigate the relationship between time and reading ability, how the growth of reading ability varies across children, and how growth varies across children as a function of selected child-level variables, such as how often parents read to child (P1READBO), how often children watch TV at weekdays (P2NUMTV), and whether children receive pre-school daycare (DAYCARE). Because no school-level variables were included, this study used two-level modeling techniques to estimate individual growth in reading ability. The level-1 sub-model addresses the question of how each child’s reading ability grows over time; the level-2 sub-model addresses the question of how growth varies across children, and how the growth trajectories vary as a function of some child-level predictors. The unconditional means model and the unconditional growth model were fitted first. Based on the unconditional growth model, variables were added to the second level to fit conditional models. In total six conditional models were fitted. The specification for each model is included in the appropriate sections below. Full maximum likelihood (ML) method was used for parameter estimation for these analyses. Estimated fixed effects and variance components are presented and discussed for the fitted models. Deviance statistics were used for model comparisons.

The SAS program (V. 9.0) was used for data analysis. SAS PROC REG and PROC GPLOT procedures were used in the first phase, and SAS PROC MIXED (procedure for mixed linear models) procedure was used for fitting multilevel models for change. The SPSS program was used to make the histograms.

Results

Preliminary analysis: Using OLS regression to smooth the children's growth trajectories of reading ability

Figure 1 shows the growth plots for 10 selected children. The plots were selected based on visual fitness of the OLS regression estimates to the data: those models fitted well and those that seemed to have poor fit. The first six plots (ID 3, 7, 9, 23, 41 and 48) showed the linear model fitted nearly perfectly. Each fitted reading score at the corresponding month was closely similar to the observed reading score. After regressing reading score on MONTH for each child, the R-squares (Table 2) for these selected children ranged from .96 to .99, indicating that the variance of children's reading scores could be nearly perfectly accounted for by MONTH. The last four plots (ID 38, 17, 24 and 30) showed observed and fitted values that were much more disparate, indicating that the OLS regressions for these children estimated the observed data poorly. The growth trajectories of these four children displayed curvilinear shapes. The R-squares for ID 38, 17, 24, and 30 were .50, .79, .81, and .79 respectively. These statistics were much lower than those of the above six, indicating the variances of reading scores for these four children were not well explained by MONTH, compared to those for the six children above. Therefore, the quality of OLS regression model fit varied considerably from child to child. The linear growth trajectory modeled the reading growth well for some children such as ID 3, 7, 9, 23, 41 and 48, but poorly for children such as ID 38 and 17.

Regression equations of the 10 representative children above were determined as follows:

For ID 3, CREAD= 21.55+1.19MONTH;
For ID 7, CREAD= 27.90+1.54MONTH;
For ID 9, CREAD= 31.20+2.08MONTH;
For ID 23, CREAD= 21.23+2.34MONTH;
For ID 41, CREAD=27.01+1.41MONTH;
For ID 48, CREAD=19.89+1.29MONTH;
For ID 38, CREAD= 29.30+4.74MONTH;
For ID 17, CREAD=49.32+1.46MONTH;
For ID 24, CREAD=52.2+1.14MONTH;
For ID 30, CREAD=15.31+1.84MONTH.

OLS regression was used to estimate within-child reading ability change over time in MONTHS. Each intercept estimated that child’s reading ability when he/she entered kindergarten (month 0). The slope in each OLS regression model estimated the monthly rate of change in reading ability for each child. Table 2 shows the OLS growth parameter estimates for each child over time. All the slopes were positive, which indicated that all children’s reading ability tended to grow (increase) as age of child in months increased. Larger slopes indicated stronger estimated growth in reading ability.

Most R-square statistics were large, indicating that time and IRT reading scores were strongly correlated, therefore, reading ability growth was strong for most of the children. As seen in Table 2, the initial status and rate of change between children varied considerably, indicating there was a great variability in children's initial reading ability and rate of change between children.

Histograms (Figure 2) of initial status and rate of change also show that there is great variability in initial status and rate of change across this small subsample of children selected for the OLS analyses (n=337). The distributions of both initial status and rate of change were close to normal. There was a great difference in the estimated children's initial reading score when they entered kindergarten, ranging from -30 to 75. These negative estimated values were problematic, because it made no sense for children to get negative IRT reading scores at the beginning of schooling. Therefore, the OLS regression did not provide good estimates for some children. The distribution of the residual variance for each OLS regression across children was positively skewed, indicating most residual variances were small. The distribution of R-square was negatively skewed, with the mean=.903, indicating the fit was accurate for most of the children. However, it was highly noticeable that considerable variability existed in the R-square statistics, ranging from the minimum .16 to the maximum close to 1.0.

Using multilevel models to analyze the data

In the following two-level models, level-1 sub-model addressed the question of how child's reading ability grew over time; level-2 sub-model addressed the question how the growth varied across children, and how change trajectories varied as a function of how often parents read to children (P1READBO), the number of hours children spend on watching TV on weekdays (P2NUMTV), and whether children receive pre-kindergarten daycare (DAYCARE).

The unconditional means model and the unconditional growth model were fitted first. Table 3 shows the results of fixed effects and random effects for these two models (Model A and Model B respectively).

The unconditional means model can be expressed like this:

$$Y_{ij} = \pi_{0i} + \varepsilon_{ij}$$
$$\pi_{0i} = \gamma_{00} + \xi_{0i}$$

Model A of Table 3 presents the results of fitting the unconditional means model to the ECLS-K sample data. For the fixed effect, γ_{00} = 37.35, $p<.0001$, indicating the estimated grand mean of READING across all occasions and children was 37.35, which was significant different from zero. For the random effects, the estimated within-person variance, $\sigma_\varepsilon^{\ 2}$ = 240.14, $p<.0001$, indicating there was considerable variability in reading ability for each child over time; the estimated between-person variance, $\sigma_0^{\ 2}$ = 97.49, $p<.0001$, indicating there was great variability in overall reading ability between children, summarized (or averaging) across all four time points. Because both variance components were significantly different from zero, there was a possibility for adding predictors to the model to explain both within-person and between-person variation in reading ability. The population intraclass correlation coefficient $\rho= \sigma_0^{\ 2}/(\sigma_0^{\ 2}+ \sigma_\varepsilon^{\ 2})$ =97.49/(240.36+97.49)=.29 , indicating 29% of the total variation in reading ability could be attributed to differences between children.

The unconditional growth model can be expressed like this:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\ TIMEMOS_{ij}+ \varepsilon_{ij}$$

$$\pi_{0i} = \gamma_{00} + \xi_{0i}$$
$$\pi_{1i} = \gamma_{10} + \xi_{1i}$$

Model B of Table 3 presents the results of fitting the unconditional growth model to the ECLS-K sample data. For the fixed effect, $\gamma_{00} = 20.49$, $p<.0001$, indicating the starting point of population average change trajectory of READING is 20.49, which was significantly different from zero; $\gamma_{10} = 1.68$, $p<.001$, indicating the slope of population average change trajectory of READING was 1.68, which was significantly different from zero, therefore, for each point increase in study month $TIMEMOS_{ij}$, there was a corresponding average 1.66 points increase in READING. For the random effects, the estimated within-person variance, $\sigma_\varepsilon^{2} = 32.42$, $p<.0001$, indicating average variance of an individual's observed reading ability around his/her true change trajectory was 32.42. Comparing σ_ε^{2} in Model B to that of Model A, there is a decline of .86 (Pseudo R_ε^{2}=(240.14-32.42)/ 240.14), indicating 86% of the estimated within-person variation was systematically associated with the TIMEMOS. Because $p<.0001$, there was significant variation remaining in level-1, which could be explained after some important predictors were introduced in the model. In level-2 variance components, $\sigma_0^{2} = 108.33$, $p<.001$, indicating there was significant unpredicted variability in true initial status. $\sigma_1^{2} = .18$, $p<.0001$, indicating there was significant unpredicted variability in true rates of change. Because both variance components in level-2 were significant different from zero, some child-level predictors could be added to the level-2 model to help explain the variation in initial status and rate of change (In the following models, three child-level variables: centered P1READBO, centered P2NUMTV and DAYCARE were added to the level-2 sub-model based on the research questions of interest). The population covariance of the level-2 residuals σ_{01}=1.21, $p<.0001$. The correlation coefficient between the initial status and true rate of change could be expressed as $\sigma_{01}/(\sigma_0{}^2 * \sigma_1{}^2)^{1/2}$=1.21/ =.27 , therefore, the relationship between the true initial status in the first month and true rate of change in reading ability was positive but small. It can be concluded that children who had good reading ability when they entered the kindergarten tend to perform a little better in reading ability gain over time.

Model A and Model B were compared using deviance statistics. ΔD=120021.1 – 101015.6 =19005.5, which was much larger than the .05 critical value of χ^2 distribution on 3 degree of freedom, 7.815, therefore, the unconditional growth model provided a better fit than the unconditional means model.

In the following, Models C, D, E, F, G, and Model H were fitted by introducing P1READBO2, the centered P1READBO (how often parents read books to their children) at its grand mean, 3.31, centered P2NUMTV at its grand mean 1.97, and DAYCARE as the predictors to level-2 sub-model. Tables 3 and 4 display the results of fixed effects, variance components and fit indices for each model. Each model was compared with its corresponding nested model by using deviance statistics.

Model C included P1READBO2 as a predictor in initial status. The model could be expressed as follows:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\,\text{TIMEMOS}_{ij} + \varepsilon_{ij}$$
$$\pi_{0i} = \gamma_{00} + \gamma_{01}\text{P1READBO2}_i + \xi_{0i}$$
$$\pi_{1i} = \gamma_{10} + \xi_{1i}$$

Because the unconditional growth model (Model B) was nested within Model C, deviance statistics was used. ΔD=101015.6-90080.3=10935.3, which was much larger than the .05 critical value of χ^2 distribution on 1 degree of freedom, 3.841, $P<.05$, therefore, the parameter, γ_{01} was significantly different from zero. We concluded that Model C provided a better fit than the unconditional growth model (Model B).

Model D included P1READBO2 as a predictor in both initial status and rate of change. The model could be expressed as follows:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\ TIMEMOS_{ij} + \varepsilon_{ij}$$
$$\pi_{0i} = \gamma_{00} + \gamma_{01} P1READBO2_i + \xi_{0i}$$
$$\pi_{1i} = \gamma_{10} + \gamma_{11} P1READBO2_i + \xi_{1i}$$

Because Model C was nested within Model D, deviance statistics was also used. ΔD=90080.3-90070.2=10.1, which was larger than the .05 critical value of χ^2 distribution on 1 degree of freedom, 3.841, therefore, Model D provided a better fit than Model C.

Model E only included centered P2NUMTV as a predictor in initial status. The model could be expressed as follows:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\ TIMEMOS_{ij} + \varepsilon_{ij}$$
$$\pi_{0i} = \gamma_{00} + \gamma_{02}\ P2NUMTV2_i + \xi_{0i}$$
$$\pi_{1i} = \gamma_{10} + \xi_{1i}$$

From the results of Model E in Table 1, γ_{02}=-.06, which was not significant. Therefore, the centered P2NUMTV was not necessary to be added in level-2 sub-model, and was trimmed out.

Model F included DAYCARE as a predictor in the initial status and Model G included DAYCARE in both initial status and rate of change. The models could be expressed in the similar forms as Model C and D. The estimated parameters of DAYCARE in both models were significantly difference from zero. The deviance statistics (ΔD=101015.6-100912.0=103.6, which was larger than 3.84, the critical value of χ^2 distribution on 1 degree of freedom at .05 level) indicated that Model F provided a better fit than the unconditional growth model (Model B), and Model G fitted better than Model F (ΔD=100912.0-100906.8)=5.2, which was also larger than 3.84.

In the final model H (Table 4), centered P1READBO and DAYCARE were included as predictors in both the initial status and rate of change. The model can be expressed as follows:

$$Y_{ij} = \pi_{0i} + \pi_{1i}\,\mathrm{TIMEMOS}_{ij} + \varepsilon_{ij}$$
$$\pi_{0i} = \gamma_{00} + \gamma_{01}\mathrm{P1READBO2}_i + \gamma_{02}\,\mathrm{DAYCARE}_i + \xi_{0i}$$
$$\pi_{1i} = \gamma_{10} + \gamma_{11}\mathrm{P1READBO2}_i + \gamma_{12}\,\mathrm{DAYCARE}_i + \xi_{1i}$$

Because both Model D and Model G were nested within Model H, deviance statistics were also used for both comparisons. Comparing Model H with Model D, ΔD=90070.2-90043.2=27, which was larger than the .05 critical value of χ^2 distribution on 2 degree of freedom, 5.99, therefore, Model H provided a better fit than Model D. Comparing with Model H with Model G, ΔD=100906.8-90043.2=10863.6, which was much larger than χ^2, 5.99, on 2 degree of freedom at .05 level, $p<.05$. Therefore, Model H provided a better fit than both Model D and Model G, and Model H was the tentative final model that was fit for the purpose of this demonstration paper.

Interpreting the Fixed Effects of Model H

For the fixed effects in Model H, the average initial reading ability for children who did not receive pre-kindergarten daycare (DAYCARE=0) and whose parents read book at average times (3.31) is 21.04 (γ_{00}). After controlling for the effect of DAYCARE, for each unit increase in centered P1READBO (P1READBO-3.31), there were 2.64 points increase in the average initial reading ability. The average rate of change in reading ability for the children whose parents read at average times was 1.69 (γ_{10}), since the parameter of DAYCARE in the rate of change was not significant different from zero. For each unit increase in centered P1READBO, there was .04 unit increase in the rate of change of reading ability. Therefore, centered P1READBO was positively associated with the initial status and the rate of change in reading growth.

After controlling for the effect of centered P1READBO, the relationship between pre-kindergarten daycare and children's reading ability was positive, and children who received pre-kindergarten daycare were estimated to be 1.61 points higher in initial reading ability than those did not receive the daycare. However, there was no significant difference between children who received pre-kindergarten daycare and those who did not attend center-based daycare in the average rate of change in children's reading ability development from kindergarten to the end of the first grade (γ_{12}= -.003, p=.83). Pre-kindergarten daycare was positively associated with initial reading ability when children just entered the kindergarten (Month 0), but was not associated with rate of change of reading ability development. Therefore, after controlling for the effect of P1READBO, for children who did not receive pre-kindergarten daycare, the rate of change in reading ability was 1.69 (γ_{10}) over time.

Interpreting the Random Effects for Model H

Comparing the variance components in Model H to those in the unconditional growth model B, it was found that σ_ε^{2}, σ_0^{2}, and σ_1^{2} all were reduced. Because no time-varying predictors were added to the level-1 sub-model in Model H, the slight decline in within-person variation might be due to iteration estimation. Estimated between-child variation in the initial status estimates, σ_0^{2}, declined by 36.43% ((108.33-

68.86)/108.33=36.43%) from Model B, and for slope variance, estimated $\sigma_1^{\ 2}$ declined by 39% ((.18-.11)/.18=39%) from Model B. Therefore, DAYCARE and centered P1READBO could explain 36.43% of the variation in initial status, and centered P1READBO could explain 39% of the variation in the rate of change. The population covariance of the level-2 residuals σ_{01}=.93, $p<.001$, and the correlation coefficient $\rho=\sigma_{01} /(\sigma_0^{\ 2} * \sigma_1^{\ 2})^{1/2}$=.93/2.75=.34, so the relationship between the true initial status in the first month and true rate of change in children's reading ability development was still positive and small. Because $\sigma_0^{\ 2}$, and $\sigma_1^{\ 2}$ were significantly larger than zero, the rejection of the null hypothesis of no residual variation remaining suggests that additional predictors need to be identified and introduced to models of both initial status and rate of change in order to account for the remaining variation in these effects.

Prototypical growth trajectories of reading ability

In order to get a visual impression how frequency of parental reading and attendance at pre-kindergarten daycare affects kindergarten entry reading ability as well as growth of reading ability, the growth trajectories of reading ability were plotted based on the final fitted model (Model H), using prototypical values of these two variables. The final model (Model H) could be expressed as a composite multilevel model like this:

$$Y_{ij} = \gamma_{00} + \gamma_{10}\ TIMEMOS_{ij} + \gamma_{01}\ P1READBO2_i + \gamma_{02}\ DAYCARE_i + \gamma_{11} P1READBO2_i * TIMEMOS_{ij} + (\varepsilon_{ij} + \xi_{0i} + \xi_{1i}\ TIMEMOS_{ij}).$$

By substituting in the estimated values for the fixed effects, the estimated Y_{ij} =21.04+ 1.69*$TIMEMOS_{ij}$ +2.64* $P1READBO2_i$ +1.61* $DAYCARE_i$ +.04* $P1READBO2_i$* $TIMEMOS_{ij}$. The prototypical values for P1REABBO2 were chosen by its grand mean

(3.31) +/- one standard deviation (.76), so high P1READBO2 was 3.31+1SD=4.07, and low frequency of reading was 3.31-1SD=2.55. Since DAYCARE was a dichotomous variable with 1 indicating children who received pre-kindergarten daycare, and 0 indicating children who did not receive, 1 and 0 were chosen as prototypical values. Figure 3 display the prototypical trajectories of the final model (Mode H). The fitted trajectories of reading ability gain differed by both how often parents read books to their children (P1READBO) and pre-kindergarten daycare children received (DAYCARE). At each level of DAYCARE, children whose parents read books more frequently to them (high P1READBO) tended to have higher reading ability over time. The slope of the prototypical change trajectory was higher for children whose parents read more often than those whose parent read less, although given the scale of the graph this difference is hard to detect visually. Controlling for how often parents read to their children, children who received pre-kindergarten daycare tended to have higher reading ability gain.

Discussion

In this study, OLS regression and multilevel modeling for change were used to investigate the growth trajectories of children's reading abilities, and how the trajectories vary across children. In particular, we were interested in understanding how child-level variables, such as how often parents read to children, the number of hours children spend on watching TV on weekdays, and whether children receive pre-kindergarten daycare, affect the within-individual difference and inter-individual difference in the growth trajectories. Results of OLS regressions and the multilevel modeling indicated that children's reading ability improved considerably during the first two years of schooling, which support the earlier findings of Denton and West (2002). However, there is great variability in individual change over time, i.e., we demonstrated that there is great variability in initial reading ability and rate of change across children. When children entered kindergarten, there were great differences between their reading abilities, and their reading abilities continued to vary as time went on. An additional finding was that the relationship between the initial status and rate of change in reading ability was positive and small. Therefore, children who had better reading abilities when they entered kindergarten tended to perform a little better in reading ability gain over time.

We found two child-level variables, how often parents read to children, and whether children receive pre-kindergarten daycare were significant predictors of the growth trajectories – either initial status or rate of change. How often parents read to their children was positively associated with initial status and rate of change of reading growth. Children whose parents read to them more often each week tended to have higher reading abilities when they entered kindergarten, and their abilities grew stronger over time, compared to children whose parents read to them less frequently. However, pre-kindergarten daycare was positively associated with initial status of reading ability, but not associated with rate of change, so the reading ability gap between children who received pre-K center-based daycare and those who did not existed in the initial status, and this gap was constant over time (although our analyses suggest that this gap is narrowing). Children who received pre-kindergarten daycare tended to perform better when they just entered kindergarten, but pre-kindergarten day-care was not a significant predictor of the rate of change. In addition, we found no significant effect of the number of hours children spend on watching TV on weekdays on either of the growth parameters for reading ability.

Although tentative, our findings do suggest efforts for improving early-reading skills. Considering the within-individual differences and inter-individual differences in reading growth, teachers may need adaptive strategies to reach all the varied levels of achievement present in their classrooms and help all students achieve their potential. With budget problems, encouraging volunteers in the classroom may be one effective solution to help teachers address these differences and reach all their students. Students with weak reading skills on kindergarten entry should be provided with extra assistance so that they will not be behind their peers as their school-years continue. For school administrators and policy makers, feasible actions suggested by our results include encouraging parents to read to their children, perhaps supplying free books or working with local libraries, and working to strengthen parents' collaborations with the schools and their children's teachers, could be considered to ensure the highest quality learning experiences for children.

There were several limitations in this study. First, we used a very narrow subset of children drawn from the ECLS-K for these analyses, which may not be representative of all children in kindergarten and first grade. Second, after the two child-level variables were added to the model, considerable variation in initial status and rate of change still exists. Therefore, some additional important potential predictors, such as gender, language spoken at home, student SES, child health and child motor skills, may need to be introduced to models of both initial status and rate of change in order to explain this residual variation. Third, a nonlinear growth model could be fitted, although with only four time-points, this complexity may not be reasonable for this data. In the analyses of both OLS regressions and multilevel modeling, the relationship between time and reading ability was assumed to be linear. The results of the OLS regressions indicated that the growth trajectories of some children displayed curvilinear shapes, so a linear function might not be the most appropriate model for at least some of these children. In a future study, we will try to fit a nonlinear growth model, and compare it with the linear model above, to see which model offers better fit to the data. Fourth, the effects of summer vacation on the reading growth were not examined here, but could be examined in a future study. The prototypical growth trajectories of reading ability (Figure 3) shows that the rate of change slows somewhat from the 8^{th} month to 12^{th} month, when children spent the summer vacation between kindergarten and first grade. Finally, a three-level model should be fitted to determine the effect of school-level characteristics, such as school SES or school type (public or private) on the growth trajectories of children's reading abilities.

References

Denton, K., and West, J. (2002). *Children's Reading and Mathematics in Kindergarten and First Grade* (NCES 2002-125). U.S. Department of Education, NCES. Washington, DC: U.S. Government Printing Office.

Denton, K., West, J., & Walston, J. (2003). *Reading-Young Children's Achievement and Classroom Experience: Findings from the Condition of Education* (NCES 2003-070). U.S. Department of Education, NCES. Washington, DC: U.S. Government Printing Office.

Draper, D. (1995). Inference and hierarchical modeling in the Social Sciences. *Journal of Educational and Behavioral Statistics,* 20(2), 115-147.

Kreft, I. G. G. (1995). Hierarchical linear models: Problems and prospects. *Journal of Educational and Behavioral Statistics,* 20(2), 109-113.

Hanson, R. A., & Farrell, D. (1995). The long-term effects on high school seniors of learning to read in kindergarten. *Reading Research Quarterly*, 30, 908-933.

Liu, X., & O'Connell, A.A. (2004 October). *An application of HLM to estimate the school and children's effects on reading achievement.* Paper presented at the 35th Northeastern Educational Research Association annual meeting. Kerhonkson, New York.

McCoach, D. B., & O'Connell, A. A. (2003, April). *An examination of students' reading growth over the first two years of school using structural equation modeling and hierarchical linear modeling techniques.* Paper presented at the annual conference of the American Educational Research Association, Chicago, IL.

O'Connell, A. A., & McCoach, D. B. (2004). Application of hierarchical linear models for evaluations of health interventions: Demystifying the methods and interpretation of multilevel models. *Evaluation & the Health Professions*, 27(2), 119-151.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: Applications and data analysis methods (2nd Edition).* Thousand Oaks, CA: Sage.

Rathbun, A. H., & Hausken, E. G. (2003). *Reading and Writing Instruction in Kindergarten: How Often and Who Receives It?* The ERIC Database ED477856.

Singer, J. D. (1998). Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. *Journal of Educational and Behavioral Statistics*, 24(4), 323-355.

Singer, J. D., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence.* London: Oxford University Press.

United States Department of Education (2001). *ECLS-K Base Year Public-Use Data Files and Electronic Code Book*. Washington, D.C.: U. S. Department of Education.

United States Department of Education (2002). *ECLS-K First Grade Public-Use Data Files and Electronic Code Book*.. Washington, D.C.: U. S. Department of Education.

United States Department of Education (2002). *Children's Reading and Mathematics Achievement in Kindergarten and First Grade*. Washington, D.C.: U. S. Department of Education.

Willet, J. B., Singer, J. D., & Martin, N. A. (1998). The design and analysis of longitudinal studies of development and psychopathology in context: Statistical models and methodological recommendations. *Development and Psychopathology*, 10, 395-426.

Table 1: Descriptive Statistics for Child-level Variables

Variable	N	M	SD
C1READ (IRT reading score of kindergarten in the fall of 1998)	3250	23.94	9.14
C2READ (IRT reading score of kindergarten in the spring of 1999)	3347	34.47	11.15
C3READ (IRT reading score of first grade in the fall of 1999)	3387	39.69	12.64
C4READ (IRT reading score of first grade in the fall of 2000)	3434	57.35	13.28
P1READBO (how often parents read to children)	3242	3.31	.76
P2NUMTV (the number of hours children watch TV on weekdays)	3394	1.97	2.15
DAYCARE (pre-kindergarten daycare received)	3529	.76	.43

P1READBO: 1= not at all; 2= once/twice per week; 3= 3 to 6 times per week; 4= everyday.
P2NUMTV: 0 to 24.
DAYCARE: 1= yes; 0= no.

Table 2: Growth Parameter Estimates (OLS) (First 30 and last 30 children included)

Obs	id	status	change	resvar	rsquare	status SE	change SE
1	1	8.8304	1.08418	21.035	0.85319	3.9207	0.31801
2	2	9.4665	1.2225	18.555	0.89335	3.6823	0.29868
3	3	21.5465	1.18812	3.929	0.97393	1.6945	0.13744
4	4	18.7768	2.38755	61.288	0.90631	6.6923	0.54282
5	5	20.235	1.28278	17.509	0.90719	3.577	0.29013
6	6	21.514	1.95297	46.719	0.89463	5.843	0.47393
7	7	27.8962	1.53626	0.785	0.99681	0.7574	0.06143
8	8	18.5462	1.84488	28.934	0.92444	4.5983	0.37297
9	9	31.2048	2.07602	8.195	0.9907	2.5008	0.20109
10	10	35.0272	2.73561	80.47	0.90629	7.6685	0.62199
11	11	19.2333	1.73927	14.427	0.95615	3.247	0.26337
12	12	18.2427	1.5237	35.68	0.87125	5.1063	0.41417
13	13	20.1556	1.93516	57.475	0.8714	6.4808	0.52566
14	14	16.3972	1.77976	21.03	0.93999	3.9203	0.31797
15	15	21.8965	0.8695	12.686	0.86107	3.0447	0.24696
16	16	19.8293	1.61862	39.15	0.87437	5.3488	0.43385
17	17	49.319	1.45953	60.673	0.78501	6.6587	0.54009
18	18	13.7155	1.51025	22.452	0.91353	4.0506	0.32854
19	19	12.448	2.01585	30.896	0.93188	4.7516	0.3854
20	20	24.2607	2.18348	110.286	0.81804	8.9774	0.72816
21	21	34.0853	2.12342	19.039	0.96098	3.73	0.30254
22	22	8.553	1.88628	52.756	0.87522	6.2091	0.50362
23	23	21.2332	2.33933	25.118	0.95773	4.2843	0.3475
24	24	52.204	1.14178	32.709	0.80564	4.8891	0.39656
25	25	23.582	1.68738	19.394	0.93853	3.7646	0.30535
26	26	12.3866	1.73579	58.016	0.84378	6.5113	0.52813
27	27	33.7025	2.14503	42.295	0.91879	5.5595	0.45093
28	28	20.2715	1.50115	15.13	0.93936	3.3251	0.2697
29	29	19.2562	2.02408	52.177	0.8909	6.1749	0.50085
30	30	15.3071	1.84429	94.501	0.78918	8.3102	0.67404
308	308	1.0367	2.79113	47.968	0.9441	5.9206	0.48023
309	309	-12.7678	2.45163	350.052	0.64103	15.994	1.29728
310	310	36.2108	1.33614	3.097	0.98359	1.5044	0.12202
311	311	25.4273	1.65149	14.095	0.95266	3.2094	0.26032
312	312	11.3462	0.64758	2.872	0.93821	1.4488	0.11751
313	313	22.7472	1.07113	47.14	0.71681	5.8693	0.47606
314	314	18.9885	1.38315	2.578	0.98721	1.3725	0.11132
315	315	23.4452	1.76001	28.373	0.91906	4.5535	0.36933
316	316	17.8342	2.54598	70.545	0.90527	7.18	0.58238
317	317	11.3182	2.72395	60.705	0.92707	6.6604	0.54023
318	318	32.108	1.77838	14.938	0.95656	3.304	0.26799
319	319	36.6468	1.65849	10.435	0.96481	2.7614	0.22398
320	320	16.0623	1.47712	49.056	0.82224	5.9874	0.48564
321	321	16.4083	1.15737	67.097	0.67492	7.0023	0.56796
322	322	21.7459	2.28685	0.622	0.99941	0.7462	0.05541

323	323	13.1473	1.1633	16.093	0.89739	3.4293	0.27816
324	324	10.6864	2.13043	65.448	0.87823	6.9157	0.56094
325	325	8.8813	1.87201	264.217	0.72885	15.3755	1.1418
326	326	26.0104	1.40843	30.882	0.8698	4.7505	0.38532
327	327	13.5207	2.25295	68.766	0.88475	7.0889	0.57498
328	328	56.5472	0.63911	10.134	0.80739	2.7213	0.22073
329	329	28.1148	0.91199	23.977	0.78296	4.1859	0.33952
330	330	21.9718	1.92077	54.345	0.87594	6.3019	0.51115
331	331	25.2355	1.22688	7.657	0.95337	2.3654	0.19186
332	332	21.4969	2.25056	37.766	0.9331	5.2534	0.42611
333	333	20.3387	1.71761	39	0.88722	5.3386	0.43301
334	334	11.7569	1.43559	41.399	0.83812	5.5003	0.44613
335	335	17.7405	2.25788	40.884	0.92841	5.466	0.44335
336	336	29.4179	0.52131	1.861	0.93823	1.1661	0.09458
337	337	-5.3588	2.2432	146.8	0.78094	10.3575	0.8401

Table 3: Results of Fitting a Taxonomy of Multilevel Models for Change to ECLS-K Data (n=3534)

		Parameter	Model A (UUM)	Model B (UGM)	Model C (Conditional Model 1)	Model D (Conditional Model 2)
Fixed Effects						
Initial Status	Intercept	γ_{00}	37.35**	20.49**	22.27**	22.27**
	X1 (p1readbo2)	γ_{01}			2.77**	2.71**
Rate of change	Intercept	γ_{10}		1.68**	1.68**	1.68**
	X1 (p1eadbo2)	γ_{11}				.04
Variance Components						
Level 1	Within-person	σ_{ε}^{2}	240.14**	32.42**	28.52**	28.52**
Level 2	In initial status	σ_0^{2}	97.49**	108.33**	69.61**	69.61**
	In rate of change	σ_1^{2}		.18**	.11**	.11**
	Covariance	σ_{01}		1.21**	.92**	.92**
Goodness of Fit						
	Deviance		120021.1	101015.6	90080.3	90070.2
	AIC		120027.1	101027.6	90094.3	90086.2
	BIC		120045.6	101064.6	90136.9	90134.8

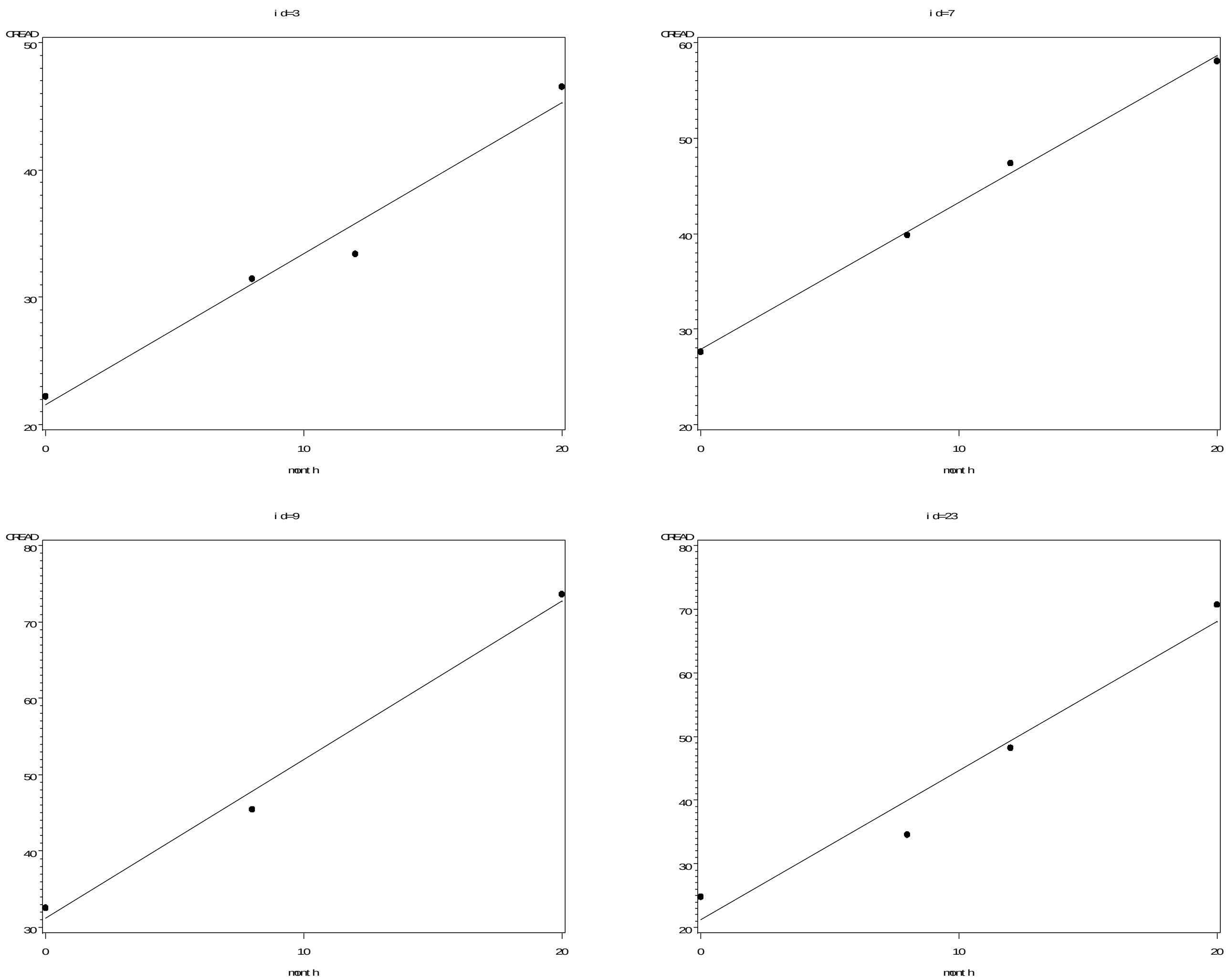
*p<.05. **p<.01.

Table 4: Results of Fitting a Taxonomy of Multilevel Models for Change to ECLS-K Data (n=3534)

		Parameter	Model E (Conditional Model 3)	Model F (Conditional Model 4)	Model G (Conditional Model 5)	Model H (Conditional Model 6)
Fixed Effects						
Initial Status	Intercept	γ_{00}	20.59**	17.93**	17.96**	21.04**
	X1 (p1readbo2)	γ_{01}				2.64**
	X2 (p2numtv2)	γ_{02}	-.06			
	X3 (daycare)	γ_{03}		3.46**	3.41**	1.61**
Rate of change	Intercept	γ_{10}	1.68**	1.68**	1.65**	1.69**
	X1 (p1eadbo2)	γ_{11}				.04**
	X2 (p2numtv2)	γ_{12}				
	X3 (daycare)	γ_{13}			.039*	-.003
Variance Components						
Level 1	Within-person	σ_{ε}^{2}	32.51**	32.42**	32.42**	28.52**
Level 2	In initial status	σ_{0}^{2}	109.87**	104.62**	104.61**	68.86**
	In rate of change	σ_{1}^{2}	.17**	.18**	.18**	.11**
	Covariance	σ_{01}	1.15**	1.17**	1.17**	.93**
Goodness of Fit						
	Deviance		97919.2	100912.0	100906.8	90043.2
	AIC		97933.2	100926.0	100922.8	90063.8
	BIC		97976.2	100969.2	100972.2	90124.1

*p<.05. **p<.01.

Figure 1: Growth Plots of Reading Ability for 10 Selected Children



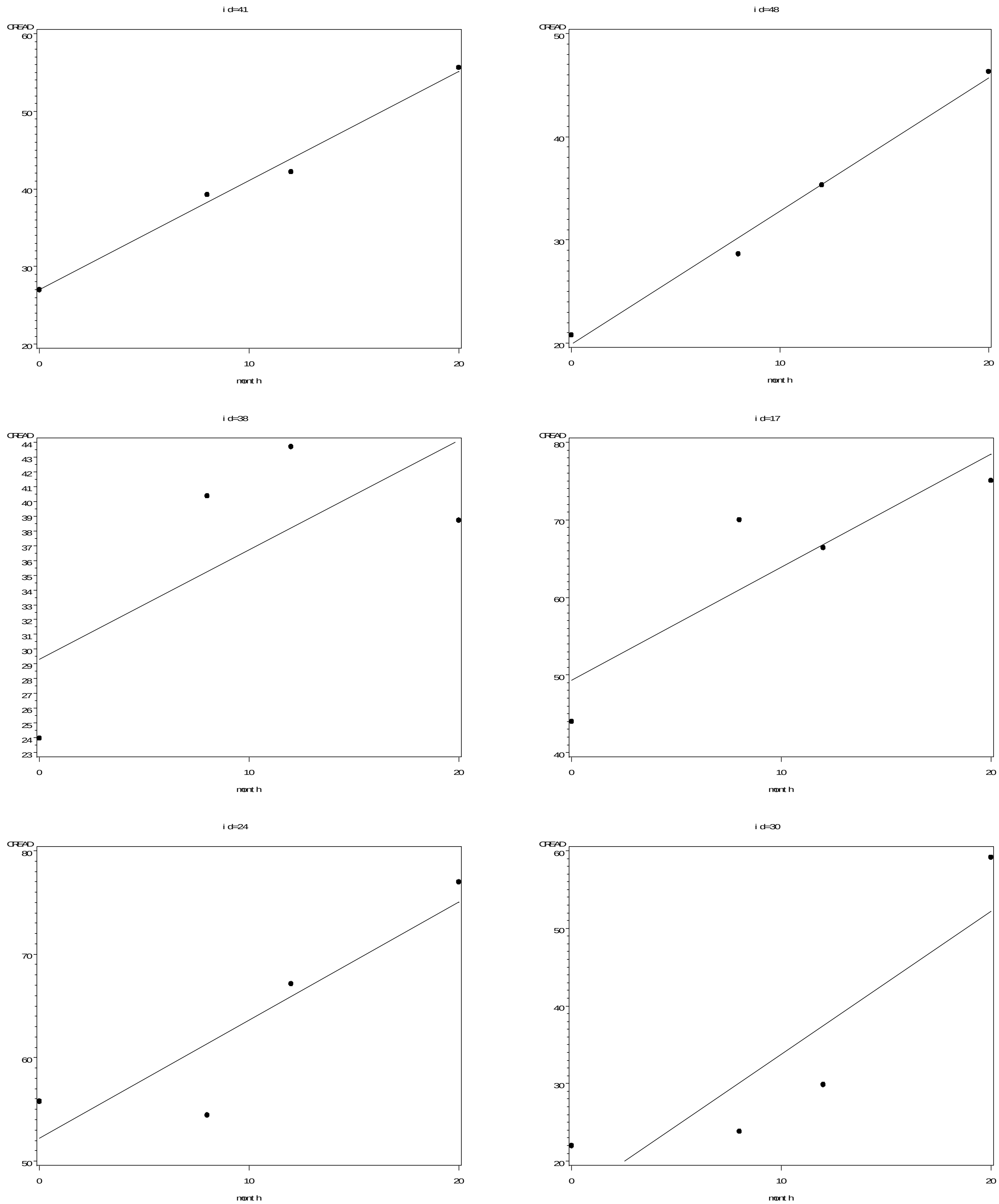

id=41
CREAD
60
50
40
30
20
0
10
20
month
id=48
CREAD
50
40
30
20
0
10
20
month
id=38
CREAD
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
0
10
20
month
id=17
CREAD
80
70
60
50
40
0
10
20
month
id=24
CREAD
80
70
60
50
0
10
20
month
id=30
CREAD
60
50
40
30
20
0
10
20
month

Figure 2: Histograms of Initial Status, Change, Residual Variance and R-square Statistics

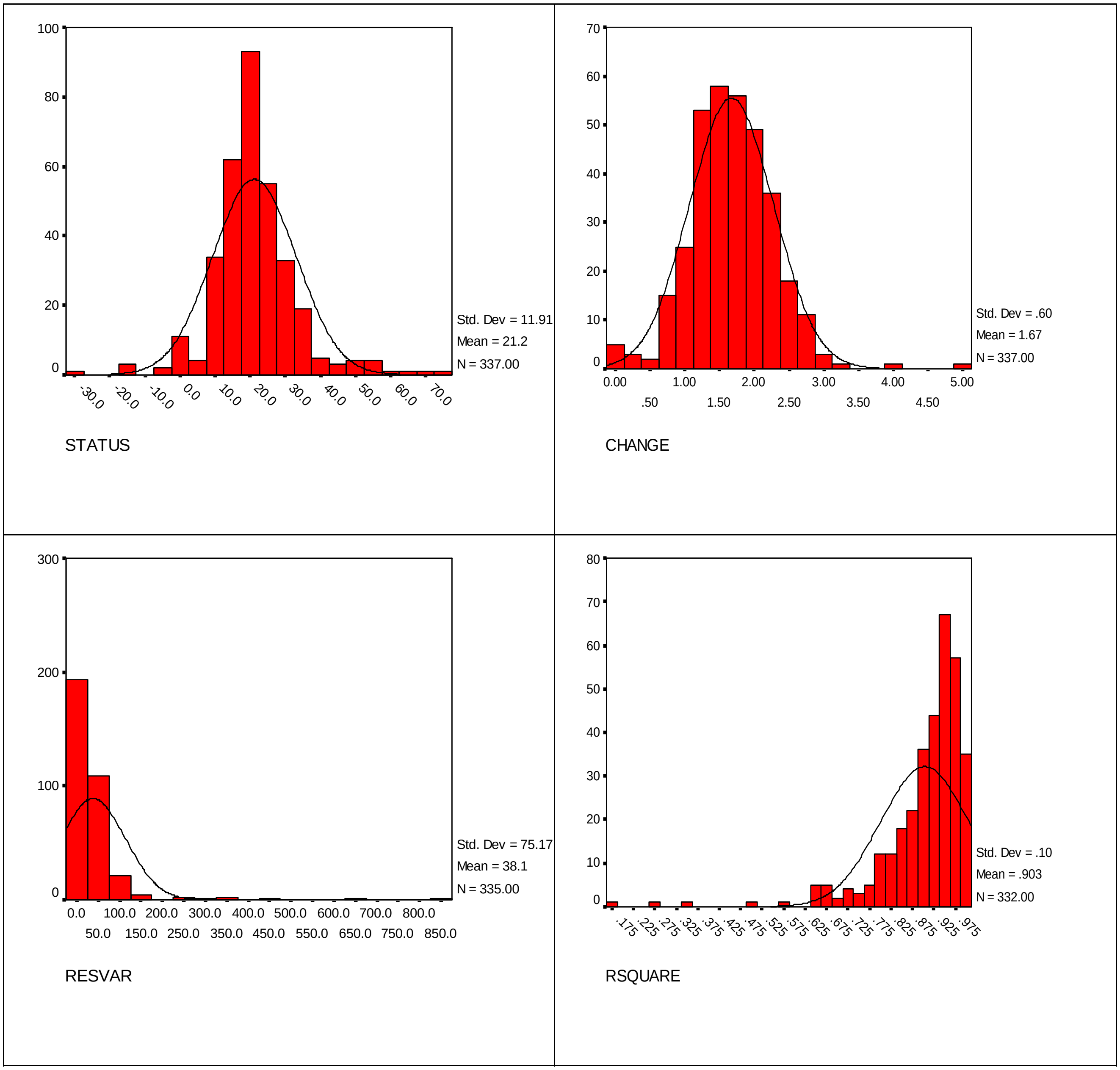


Figure 3: Prototypical Growth Trajectories of Reading Ability