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Self-regulation and the Development of Literacy and Language Achievement from Preschool through Second Grade

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Abstract

Previous research has established that higher levels of behavioral self-regulation are associated with higher levels of language and literacy. In this study, we take a more developmental perspective by considering how trajectories of self-regulation development (early, intermediate, late) predict the way literacy and language skills develop from preschool through second grade. Children (n = 351) were assessed twice per year for up to four years on indicators of decoding, reading comprehension, phonological awareness, and vocabulary. Using non-linear growth curve models, we found that children who demonstrated self-regulation earlier had higher language and literacy skills throughout preschool to second grade. More specifically, earlier self-regulation trajectories were associated with both higher levels and earlier development of both decoding and reading comprehension, but not faster development. Children with early self-regulation trajectories developed phonological awareness earlier than those with late self-regulation trajectories. Finally, children with early self-regulation trajectories had higher levels of vocabulary than children with intermediate trajectories, but did not differ on the rate or timing of vocabulary development. Findings point to the enduring and interconnected nature of self-regulation and children's language and literacy development.

Self-regulation is an umbrella term that encompasses the socio-emotional (Campos, Frankel, & Camras, 2004), physiological (Fjell, Sneve, Grydeland, Storsve, & Walhovd, 2017; Wilson, Lengua, Tininenko, Taylor, & Trancik, 2009), and cognitive (Best & Miller, 2010; Clark et al., 2016) skills that assist children in controlling and planning their behaviors. It has been argued that self-regulation is a core school readiness skill (Blair, 2002; Blair & Diamond, 2008; Blair & Raver, 2015) because higher levels of self-regulation at specific

ages predict higher levels of social, cognitive, and academic outcomes at various points during children's years in school as well as in adulthood (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013; McClelland, Cameron Ponitz, Messersmith, & Tominey 2010; Mischel et al., 2011; Moffitt et al., 2011; Zelazo, Blair, & Willoughby, 2016). Because of this predictive power, self-regulation has been a prime target for intervention during children's years in preschool (Schmitt, McClelland, Tominey, & Acock, 2015; Tominey & McClelland, 2011) and beyond (e.g., Abrami, Venkatesh, Meyer, & Wade, 2013; Pears, Fisher, & Bronz, 2007). It is also targeted as part of some early childhood curricula (e.g., *Tools of the Mind*, Bodrova & Leong, 2007).

However, work in this area has generally considered the levels of skills in a static manner-where a child is at one or two particular points in time-rather than examining the way a child is developing in a dynamic framework (Matthews, Ponitz, & Morrison, 2009; McClelland, Cameron, Connor, Farris, Jewkes, & Morrison, 2007). Development is a process that cannot be fully captured with one or two measurement points, and a dynamic framework is necessary for a more complete understanding of development (Molenaar, 2004; Nesselroade & Schmidt McCollam, 2000). For example, consider two children, A and B, where child A is observed with higher self-regulation skills at age 4. One possible explanation is that child A had and will have higher self-regulation skills at all ages than child B, such that development occurs in parallel but at different levels. Alternatively, child A may have started developing self-regulation skills at an earlier age, but child B, although developing later, will ultimately reach the same level of self-regulation skills. Identifying whether differences in self-regulation between child A and child B at age 4 are due to level differences or developmental timing differences may offer important insights about the nature of self-regulation. Furthermore, in their seminal exposition of lifespan developmental psychology, Baltes and Nesselroade (1979) highlight the importance of examination of not just development (in their terminology, intraindividual change), but also interrelations of development on multiple variables: how development of one skill is related to development of other skills. In this study, we take this perspective by expanding research on self-regulation to consider not just the level of self-regulation, but how self-regulation develops, and how this relates to academic skills: not just the levels of academic skills, but also how the skills develop.

Specifically, the present work examines further whether the emphasis on self-regulation as a core school readiness skill is warranted by examining how individual differences in the *development* of behavioral self-regulation are related to individual differences in the *development* of children's language and literacy skills from preschool through second grade. Here we conceptualize and operationalize development more fully than just the level of a child's skills at a particular age, and more fully than the level and rate of change conceptualization employed in longitudinal studies that use latent growth curve modeling (e.g., Lonigan, Allen & Phillips, 2017), by considering the timing of development and the rate of development in addition to the level of skills. Furthermore, this study provides a more sophisticated conceptualization of development by considering interrelations of development of self-regulation and development language and literacy skills. This focus provides a more complete picture regarding how self-regulation development affects the level of literacy and

language skills during early childhood, the rate of growth in those skills, and the timing of the skill development.

Development of Self-Regulation

Children's self-regulation develops rapidly during early childhood (Jones, Rothbart, & Posner, 2003) and interconnects with a constellation of systems, from the expression of genes to the experiences provided by social interactions (Blair & Diamond, 2008; Blair & Raver, 2012). The current study focuses on one facet of self-regulation, behavioral self-regulation, which represents a key aspect of self-regulation during children's early school years (Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; McClelland et al., 2014). Behavioral self-regulation relies upon children's ability to integrate their attention, working memory, and inhibitory control to manage their behaviors. Behavioral self-regulation generally develops in a monotonic but nonlinear fashion across early childhood, with many individual differences regarding when children can self-regulate their behaviors (Cameron Ponitz, McClelland, Jewkes, Connor, Farris, & Morrison, 2008; Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016; Wanless, Kim, Zhang, Degol, Chen, & Chen, 2016). For a substantial portion of three year olds, the coordination of the multiple skills required for behavioral self-regulation can be challenging, resulting in floor effects on some measures of behavioral self-regulation (Cameron Ponitz et al., 2008). One reason for this is that many three year olds are only capable of tasks that predominantly require one skill at a time and must further develop the capacity to integrate skills; however, most children are able to coordinate the use of multiple skills before age five (Gestaldt, Hong, & Diamond, 1994: Kochanska, Coy, & Murray, 1996).

Recently, researchers have worked to systematically evaluate variation in self-regulation development across early childhood (e.g., Wanless et al., 2016). Specifically, BLINDED considered data from over one thousand children collected as part of three projects from several areas in the United States, and found that there was substantial variability regarding when children were able to integrate their working memory, attention, and inhibitory control to self-regulate their behaviors during preschool, kindergarten, and first grade. In particular, three groups of children emerged for all three samples: those who demonstrated their behavioral self-regulation capacity early, in the middle (i.e., intermediate), or late. In this study, we further consider one of the samples from BLINDED, in which the early developing group had already exhibited self-regulation development at study entry in the first year of preschool (i.e., did not exhibit floor effects) and gained self-regulation rapidly, with gains tapering off after 43 months of age. Intermediate developers entered preschool with lower levels of self-regulation than the earlier developers, gained less rapidly, and tapered off only after around 53 months. Finally, late developers began with similar levels of self-regulation as the intermediate group but did not demonstrate an immediate rapid increase in self-regulation, with rapid gains not starting until after 55 months of age. These previous results provided evidence that variation in self-regulation development is systematic, with differences not just in the *level* of self-regulation, but also in *when* children demonstrate rapid development. The goal of this study is to extend these findings within a developmental framework to understand how the developmental trajectory of self-regulation

is related to the *level*, the *rate of growth*, and the *timing* of development of other academic skills.

Self-regulation and academic achievement

Evidence in recent years consistently demonstrates that levels of behavioral self-regulation in the fall of preschool predict academic achievement in that same year, a finding that is relevant across many socioeconomic strata (McClelland & Wanless, 2012; Sektnan, McClelland, Acock, & Morrison, 2010; Willoughby, Blair, & Family Life Project Investigators, 2016) as well as in different cultures (Wanless et al., 2016). In general, higher levels of behavioral self-regulation have been linked to greater levels of literacy achievement in preschool (McClelland et al., 2007), kindergarten (Matthews et al., 2009), and elementary school (Connor, Ponitz, Phillips, Travis, Glasney, & Morrison, 2010; Skibbe, Phillips, Day, Brophy-Herb, & Connor, 2012).

There are several reasons that could serve to explain why children with higher levels of self-regulation tend to have higher later levels of language and literacy. In classrooms, aspects of self-regulation related to attention are thought to help children to remember instructions and stay on task (McClelland & Cameron, 2012; Duncan et al., 2007), which help children to take advantage of classroom instruction. In addition, evidence suggests that children with low self-regulation are more likely to exhibit problem behaviors and less likely to demonstrate social competence (McCabe & Brooks-Gunn, 2007; Montroy, Bowles, Skibbe, & Foster, 2014). This could detrimentally affect children's own enjoyment of school as well as elicit negative attention from teachers (Blair & Diamond, 2008). Taken as a whole, these behaviors could interfere with individual children's ability to gain skills from classroom instruction and interrupt learning for classrooms as a whole (Montroy, Bowles, & Skibbe, 2016; Skibbe, Phillips et al., 2012).

Although many academic skills may develop in concert with behavioral self-regulation, the current study focuses on children's language and literacy development. Learning to read is one of the most important skills that children need to master during their first years in school (NELP, 2009) and this academic competency requires a constellation of language and literacy skills (Storch & Whitehurtst, 2002). At isolated points in time, self-regulation has been related to children's literacy skills (McClelland et al., 2007; Skibbe, Phillips et al., 2012); however, effect sizes vary depending on the particular language and literacy skill and when they were measured (Best, Miller, & Naglieri, 2011; McClelland et al., 2014). To add to this literature and provide a deeper understanding of the relations between self-regulation and language and literacy skills, we utilize a developmental framework to examine not just how levels of both are related, but also whether the way in which self-regulation develops is related to the way language and literacy develop. We focus on four areas of language and literacy across early childhood: decoding, reading comprehension, phonological awareness, and vocabulary.

Decoding skills

Growth in decoding occurs rapidly during early childhood, with the greatest period of growth occurring during kindergarten and first grade (Skibbe, Grimm, Bowles, & Morrison,

2012). The association between self-regulation and the development of early decoding skills appears to be complex, with some (McClelland et al., 2007), but not all (Birgisdóttir, Gestsdóttir, & Thorsdóttir, 2015), studies observing that self-regulation predicts growth in children's early decoding skills, although it is unclear whether the observed higher growth is due to faster overall growth or because children with higher self-regulation reach the point of rapid development earlier. Decoding is emphasized heavily in early childhood classrooms (Al Otaiba et al., 2008; Skibbe, Hindman, Connor, Housey, & Morrison, 2013), suggesting that children have ample opportunities to employ their self-regulation to learn this skill, so we expect that self-regulation may be related to both the rate of growth, as children with higher self-regulation learn more rapidly, and the timing of growth, as children with higher self-regulation begin to learn decoding earlier.

Reading comprehension

Although not studied widely, behavioral self-regulation has predicted children's reading comprehension in first grade (Birgisdóttir et al., 2015; Skibbe, Phillips et al., 2012). Reading comprehension requires the coordination of multiple cognitive skills, including a mix of decoding and language skills, yet also requires children to retain the information they gather from a text in their memories (Francis et al., 2006; Keenan, Betjemann, & Olson, 2008). Researchers have argued that academic skills which require more complex coordination of skills, such as comprehension, also rely more heavily on behavioral self-regulation than ones that are more rote in nature (Birgisdóttir et al., 2015; Zelazo et al., 2016). Because of the dearth of previous research, we do not have specific hypotheses regarding the relation between the development of self-regulation and the level, rate, and timing of reading comprehension development.

Phonological awareness

Phonological awareness is also consistently linked to self-regulation in preschool and kindergarten (Matthews et al., 2009; Allan & Lonigan, 2011; Blair & Razza, 2007; Lonigan et al., 2009), at least in relation to the English language, with some mixed results internationally (Aram, Abiri, & Elad, 2014). When employed in service of word reading, both phonological awareness and the ability to retain speech sounds in working memory, an aspect of self-regulation, formed a single factor representing the reading-related abilities of younger children, suggesting that these skills are highly related to one another (Lonigan et al., 2009). We therefore hypothesize that self-regulation will be related to levels of phonological awareness, but in the absence of longitudinal studies relating self-regulation to phonological awareness, we do not have specific hypotheses regarding the relation between self-regulation and the rate and timing of phonological awareness development.

Vocabulary

There is conflicting evidence about how behavioral self-regulation relates to vocabulary, with some (Matthews et al., 2009; McClelland et al., 2007; Wanless et al., 2016), but not all (Cameron Ponitz et al., 2009; Fuhs et al., 2014) studies showing that it supports growth in this area during preschool and kindergarten. Wanless and colleagues (2016) suggest that children who are able to self-regulate their behaviors earlier are more enjoyable to be around, thus allowing children to obtain more communicative interactions with teachers that

promote their language development. Support for this notion comes from work indicating that preschoolers with higher behavioral self-regulation exhibit higher social skills and fewer problem behaviors than those with lower self-regulation, which then predicts their academic achievement during that same year (Montroy et al., 2014). Based on these studies, we hypothesize that self-regulation will be related to earlier development of vocabulary, but we have no specific hypotheses regarding the level and rate of growth of vocabulary.

Current Study

To our knowledge, no study has examined how the development of behavioral self-regulation relates to the way language and literacy develop across multiple school years using multiple indicators of children's skills. The current study examines how the development of a child's self-regulation relates to the way in which the child develops core literacy skills from preschool through second grade. Using previously established trajectories (BLINDED), we investigated whether individual differences in the self-regulation trajectory a child follows (i.e., early, intermediate, or late) predict individual differences in language and literacy skill development in four key areas: decoding, reading comprehension, phonological awareness, and vocabulary. In particular, we consider how self-regulation is related to the level, rate of growth, and timing of growth of language and literacy skills. We expect that earlier development of self-regulation will advantage children's language and literacy learning, although the expected nature of that advantage is unclear based on the limited research in this area that takes a dynamic approach to development, and likely differs across language and literacy skills.

Method

Participants

Children (**n** = 383) were recruited as part of a longitudinal study that examined children's academic, cognitive, and socio-emotional functioning from preschool through second grade. From this larger sample, children were included if their behavioral self-regulation had been measured on at least two occasions over the course of the study (**n** = 351, **n** = 183 female). Missing data on the measure of self-regulation could be accounted for almost entirely by attrition and study design.

All children resided within one school district in the Midwest and attended a public preschool in the district at study entry. At the start of the study, children were on average four years of age (**M** = 48.16 months, **SD** = 7.35). Of the families who provided data on children's ethnicity (**n** = 258), parents reported that children were predominantly White/ Caucasian (82.2%), followed by Asian/Indian (5.8%), African-American (4.2%), Multiracial (3.5%), Hispanic (3.1%), and Middle Eastern (<1.0%). Maternal education was generally high (**M** = 16.14 years, **SD** = 1.86 years), as most mothers reported that they had obtained a bachelor's degree. Household income varied widely (range = $11,000 to $637,000), but the median household income was also high ($118,000). Preschool classrooms in this study followed the same academic calendar as local elementary schools and did not offer opportunities for summer instruction.

Procedure

Children were tested individually in the fall and in the spring of each year they were enrolled in the study. Each child could be followed for up to four years. Children were recruited in two waves and were assessed as many as eight times each. Children who were enrolled in the study during the first wave (**n** = 261) could be assessed from fall of the first year of preschool through spring of first grade and children enrolled as part of the second wave (**n** = 90) were possibly assessed from fall of the second year of preschool through spring of second grade. Each child was given a battery of assessments measuring their cognitive and social development at each assessment point. Although children's literacy skills were measured at every point in time, children's self-regulation was only assessed through first grade because of limits of the self-regulation assessment. These assessments took place in a quiet location in their schools and were individually administered by trained research assistants.

Measures

Language and Literacy—Four subtests of the *Woodcock-Johnson III Tests of Achievement* (*WJ-III*; Woodcock et al., 2001) were used to assess children's literacy skills. These included Letter-word Identification, Passage Comprehension, Sound Awareness, and Picture Vocabulary. Results are reported using *W* scores, the Rasch-based scores used to describe performance on the WJ-III that account for both a child's age and ability level. As a Rasch-based scale, the *W* score offers strong justification for interval scaling across the entire score continuum (Perline, Wright, & Wainer, 1979), a necessary condition for valid inference with longitudinal data (Bowles, in press).

The *Letter-Word Identification* (*LW*) subtest is comprised of 76-items that measure children's decoding skills; beginning items were chosen based on children's age and the basal rules associated with the subtest (i.e., six consecutive answers correct to establish baseline performance). Testing ended after children answered six consecutive items incorrectly. Earlier items ask children to identify letters, which are followed by items that require children to identify words that increase in difficulty as items progress. Reliability on this measure ranges from .96 to .99 for children 3 to 8 years of age.

The *Passage Comprehension* (*PC*) subtest examines children's ability to comprehend text as well as their language comprehension. Children are first asked to match a symbolic representation of a word with its picture. After these initial items, children then connect a written word with its respective picture. Later items require children to locate the word that completes a written passage most appropriately. For children ages 3 to 8, the reliability of this measure ranges from .92 to .96.

The *Sound Awareness (SA)* subtest describes children's understanding of the sound structure of language using four different types of items. Rhyming captures children's awareness of rhymes as well their ability to produce them verbally. Deletion items focus on children's ability to remove phonemes or syllables from stated words to create new words. Substitution items work similarly, but require children instead to add phonemes or syllables to stated words. Finally, phonemes or syllables are reversed or switched in words for the reversal

subscale. Sound awareness was not administered to any children in second grade. Reliability for children ages 4 to 8 ranges from .71 to .93.

The *Picture Vocabulary* (*PV*) subtest examines children's productive language skills in addition to their word knowledge. Children are shown pictures and asked to label them. Target words become more difficult as the test progresses. The established reliability for this subtest ranges from .70 to .84 for children ages 3 to 8.

Self-regulation—Children's behavioral self-regulation was measured directly using the Head-Toes-Knees-Shoulders task (HTKS; Cameron Ponitz et al., 2008; Cameron Ponitz et al., 2009; McClelland et al., 2014). This task codes children's behavior as they first comply with testers' demands (e.g., touch your head) and then children are observed as they are asked to do the opposite of what the tester says (e.g., children must touch their heads when asked to touch their toes). For each of 20 items included on the task, children can receive a score of 0 (incorrect response), 1 (self-correct an initially incorrect response), or 2 (correct initial response). Reliabilities on this task are high (e.g., alpha = .98, Ponitz et al., 2008). Within the current study, Cronbach's alpha was .85, indicating acceptable internal consistency. This measure has demonstrated strong predictive validity (McClelland et al., 2007; Wanless et al., 2011) across cultures (Lan, Legare, Cameron Ponitz & Li, 2011; Wanless et al., 2011). Furthermore, when examined in concert with similar measures designed to capture self-regulation and executive function, the HTKS loaded strongly onto a single self-regulation factor (Allan & Lonigan, 2014). Also, given that the HTKS was administered multiple times as part of the present work, it is important to note that performance on this task does not appear to be influenced by practice effects (Cameron Ponitz et al., 2008).

Analysis Plan

As a preliminary step, we used an analytical procedure from our previous study with this same sample to classify children into trajectories of self-regulation (BLINDED; the previous study also included data from two additional studies for which the language and literacy outcomes were not available). Specifically, we used growth mixture modeling to model self-regulation data with children's scores grouped into six month developmental windows across the course of the study. We parameterized growth using an exponential model. Similar to the previous study the three class solution fit best. This was determined by a combination of indices: first the bootstrapped log likelihood test that compared the three class solution to the two class solution was significant ($p < .01$; the four class solution did not converge indicating poor fit), entropy was reasonably high (0.73) indicating good class separation, and AIC and adjusted BIC favored this model compared to a two class (AIC two class: 2579 vs AIC 3 class: 2465; BIC two class 2584 vs. 2473). Finally the categories were meaningfully interpretable: early developers, characterized by children who start preschool with higher self-regulation compared to their peers and then develop rapidly over the next six months (25%), intermediate developers, who start with a low level of self-regulation compared to the early developers, but also develop rapidly over the preschool year but more slowly than early developers (46%), and late developers, who start with similar levels of self-regulation as their intermediate peers, but lag in development, growing at a slower pace

across early childhood (29%). This analysis yielded estimated probabilities of each trajectory for each child (i.e., mixture probabilities), and we classified each child into the trajectory for which the child had the highest probability of membership.[1] Based on our previous findings, the only significant demographic difference across children classified into these groups (for this sample) was related to child gender, with more boys in the late developer group than the earlier or intermediate developer group. More details about this analytical procedure are available in BLINDED.

For this study, we used nonlinear growth curve modeling to model development in each language and literacy skill separately. We used self-regulation trajectory in a multi-group analysis to consider differences in the development of literacy skills. Based on our previous findings with the same data (BLINDED), literacy growth was specified to follow a sigmoidal (S-shaped) trajectory for all language and literacy skills using a standard logistic equation reparameterized to increase parameter interpretability. The equation for the nonlinear growth curve model is

$$Lit[grade]_n = Level_n + Slope_n \cdot 4\lambda \left[\frac{1}{1 + \exp\left(\frac{-1(grade - \alpha_{sr})}{\lambda} \right)} - .5 \right] + u[grade]_n$$

where $Lit[grade]_n$ is the outcome language or literacy skill at a particular grade (e.g., fall of kindergarten) for person n, α_{sr} represents the grade at the point of maximal rate of growth for self-regulation trajectory sr (where sr is early, intermediate, or late development of self-regulation). The point of maximal rate of growth occurs at the center of the S-shape and is called the point of inflection: when growth changes from accelerating to decelerating. Level is child n's literacy score at the point of maximal growth, Slope is the child's rate of growth in literacy at the point of maximal growth, and λ is a curvature parameter associated with the logistic model. Consistent with typical approaches with latent growth curve models, Level and Slope were assumed to follow a bivariate normal distribution, with each sr group allowed to have a different mean and variance. For the analyses predicting growth in vocabulary skills, models would not converge when all groups were specified to follow sigmoidal growth, with model warnings indicating that the sigmoidal specification did not fit well for children classified as demonstrating late self-regulation development. We therefore reran the model with vocabulary as the outcome with the late developers group specified to follow linear growth. All models were estimated in Mplus 7.2 (Muthén & Muthén, 1998–2012) using a maximum likelihood approach to missingness as implemented in Mplus. An example script is provided in the supporting files.

Results

Descriptive statistics for self-regulation and literacy are included in Table 1. Correlations for all variables are provided as part of the supporting files.

[1]Simultaneous estimation of the growth mixture model and the nonlinear growth curve model was not possible due to the complexity of the analysis.

To test if language and literacy trajectories were distinct between self-regulation groups, we considered two models. In the fully constrained model, mean Level, mean Slope, and grade at maximal rate of growth were constrained to be equal across the three self-regulation trajectory groups. In the free model, all three parameters were allowed to vary across groups. For Picture Vocabulary, because late developers followed a linear model, we only considered constraints to compare early and intermediate developers. We compared the fully constrained and free models with a Wald test using the Mplus Model Test statement. For all four outcome variables, the fully constrained model added significant misfit, indicating that the developmental trajectories differed between the self-regulation trajectory groups (Letter Word Identification: $X^2 = 36.49$, df = 6, $p < .001$; Passage Comprehension: $X^2 = 52.06$, df = 6, $p < .001$; Picture Vocabulary: $X^2 = 11.48$, df = 3, $p < .01$; Sound Awareness: $X^2 = 116.74$, df = 6, $p < .001$).

We also considered six additional models where we constrained individual parameters across the groups (e.g., level) or pairs of parameters (e.g., level and slope); this allowed us to test whether group differences were related to one or two specific parameters or all three. In all cases, we selected the model with the lowest AIC and sample-adjusted BIC (aBIC). Results are provided in Table 2. For Letter Word Identification and Passage Comprehension, both AIC and aBIC supported the model with the mean Slope constrained equal but the mean Level and grade at maximal rate of growth allowed to vary across groups. Follow-up Wald tests indicated that this model did not fit significantly worse than the model with mean Slope allowed to vary (free model) for either LW ($X^2 = .96$, df = 2, $p = .62$) or PC ($X^2 = .01$, df = 2, $p = .99$). For Picture Vocabulary, both AIC and aBIC supported the model with mean Slope and grade at maximal rate of growth constrained; that is, with only level different between the early and intermediate groups (the late developing group was not included because of the linear trajectory). Follow-up Wald tests confirmed that this model did not fit significantly worse than the free model where the point of inflection and slope were allowed to vary along with the level ($X^2 = 2.12.$, df = 1, $p = .15$). For Sound Awareness, both the AIC and aBIC indicated that the fully free model where mean Level, mean Slope and grade at maximal rate of growth varied across groups best fit the data.

Finally, we investigated differences between specific self-regulation trajectory groups using a planned comparisons approach to compare early developers of self-regulation to intermediate developers, and then intermediate developers to late developers (except for Picture Vocabulary). Results are in Table 3. We first constrained the parameters identified as differing between groups in the previous analysis to be the same for the early and intermediate groups, while allowing the late group to differ from the other two groups. For all four skills, both Wald tests and AIC/aBIC indicated that the constrained model fit significantly worse, indicating that early and intermediate self-regulation developers differed in all four outcomes. We repeated the analyses, comparing intermediate to late developers, with results indicating that intermediate and late developers differed on all outcomes.

Parameter estimates for the final models are presented in Table 4 and predicted trajectories are displayed in Figures 1–4. For all outcome variables at all ages, children classified as early self-regulation developers had higher predicted values of all literacy skills between preschool and second grade compared to intermediate developers, who in turn had higher

predicted values than late developers. For both Letter Word Identification and Passage Comprehension, earlier development of self-regulation was associated with a higher mean level of the outcome at the point of maximal rate of development, as well as a younger point of maximal rate of development, indicating earlier development of the literacy skills. For Picture Vocabulary, earlier development of self-regulation relative to intermediate development was associated with a higher mean level, but no difference in the rate of growth or timing of development. Specific group differences among the parameters estimates for Sound Awareness were less consistent. Early developers were similar to late developers except for earlier grade of maximal growth by about 9 months. Intermediate developers had a lower level, higher slope, and early point of maximal development than the other two groups, but as indicated in Figure 3, the combination of these differences yields a trajectory in between early and late developers.

Discussion

Current results affirm that behavioral self-regulation plays a key role in supporting the acquisition of children's language and literacy skills (McClelland et al., 2007; Montroy et al., 2014). Many of the core skills thought to be advanced by behavioral self-regulation, including paying attention and remembering instructions, foster the learning of complex concepts (Blair & Raver, 2015; Cameron & McClelland, 2012; Duncan et al., 2007), including in the areas of language and literacy. After observing children twice per year for up to four years, we found a large and enduring advantage for developing self-regulation earlier, as children who did so had higher predicted language and literacy scores throughout the range of our study, from preschool through second grade. However, patterns of development did vary with regard to individual language and literacy skills. More information is provided about each skill below.

Decoding and Reading Comprehension

For decoding and reading comprehension, earlier self-regulation was associated with higher skills throughout the study. The rate of growth was similar across groups, consistent with previous work investigating individual differences in reading development as related to decoding (Catts, Bridges, Little, & Tomblin, 2008; Kempe, Eriksson-Gustavsson, & Samuelsson, 2011); prior work is less clear as related to reading comprehension, with individual differences in rate of development at least partially accounted for by differences in the home literacy environment (Kempe et al., 2011). However, it is important to note that early developers of self-regulation had both higher *levels* of decoding and reading comprehension, and developed these skills *earlier*. Previous work in this area has shown that, for all children, literacy skills develop rapidly during early childhood, but begin to show less rapid growth sometime in kindergarten or first grade (Skibbe, Grimm et al., 2012). In the current work, a child who had late developing self-regulation skills reached the point of most rapid growth later; furthermore, even at this later time, children's skills were at a *lower level* of expertise. Specifically, early self-regulation developers reached the point of maximal growth for decoding in the spring of kindergarten, compared to late self-regulation developers who reached the point of maximal growth about 6 months later and were a full 10 points lower even at that point of maximal growth. For reading comprehension, early

self-regulation developers showed their most rapid growth sometime between the spring of kindergarten and fall of 1st grade, compared to late developers, whose maximal growth was not reached for another six months and was 6 points lower.

Many of the skills needed to be successful when first learning to read (e.g., letter knowledge and sight word recognition) become fairly automated in preschool or kindergarten (Cameron Ponitz et al., 2009), perhaps requiring less self-regulation to complete as automaticity develops. Thus, initially, decoding likely requires self-regulation, whereas as decoding skills are mastered and become automatic, decoding may require less investment of self-regulation (Zelazo et al., 2016). Although reading comprehension requires a complex coordination of skills throughout a child's time in school, the ways in which we measured it during children's first years in school align closely with skills associated with decoding (Keenan et al., 2008). Thus, self-regulation may be a prerequisite for success with both decoding and reading comprehension. Our novel finding that self-regulation is associated with the timing of the development of decoding and reading comprehension may reflect that late developers of self-regulation are delayed in the development of decoding and reading comprehension because of an initial lack of requisite levels of self-regulation, but once the requisite level reached, the process of development of decoding and reading comprehension may be similar for all children.

Phonological awareness and Vocabulary

Developing self-regulation earlier also advantaged children's language development, as measured by children's phonological awareness and vocabulary. Findings coincide with prior research indicating that behavioral regulation predicts language outcomes (Lonigan et al., 2009; Matthews et al., 2009; McClelland et al., 2007). Similar to literacy skills, children identified as early self-regulation developers had higher levels of phonological awareness and vocabulary throughout the course of the study. For phonological awareness, children's development of self-regulation was associated with not only their levels and the grade at which they reached their maximal growth, but also their overall growth rate. Interestingly, intermediate developers reached maximal growth in early spring of their first year of preschool, whereas early developers reached their point of maximal growth in late spring/early summer. In addition, intermediate self-regulation developers also demonstrated a faster rate of growth than children in the other two groups, but their level disadvantage was too big to overcome by the close of the current study. In addition, late self-regulation developers not only had lower levels, but they demonstrated their fastest rate of growth a full year behind their early and intermediate developing peers. Overall, the largest gaps in sound awareness skills between the groups can be summarized as occurring early (e.g., in the preschool years), with both late and intermediate self-regulation developers never fully making up level differences.

The type of compensatory sound awareness development observed for the intermediate developers has been observed for other developmental domains as well (Parila et al., 2005). For example, using a national data set, Skibbe and colleagues (2008) found that children with low language skills in preschool developed literacy skills more rapidly than their peers with typical development. However, similar to the present study, initial deficits were not

fully overcome by fifth grade. Mastering concepts of self-regulation earlier might help children to manage their social interactions more effectively early on, increasing the likelihood that others will want to spend time with them, giving children more opportunities to practice their language skills (Wanless et al., 2016). For example, children who exhibit greater self-regulation tend to have higher social skills and to exhibit fewer of the problematic behaviors that might interfere with the social interactions that promote language (Montroy et al., 2014). However, children who are comparatively struggling the most with self-regulation during early childhood, the late developers, do not compensate in sound awareness. Thus, although it is promising that children who were intermediate in self-regulation development, roughly half of the sample, were able to work towards minimizing their gap in phonological awareness, evidence suggests that they would still experience an enduring disadvantage relative to peers who mastered self-regulation skills earlier.

Children's vocabulary skills demonstrated differences across the early and intermediate self-regulation groups in their levels; we were not able to directly examine parameter differences with the late self-regulation group because of model convergence issues. The grade at maximal growth was the same for both the early and intermediate groups: fall of the second year of preschool, with similar (i.e., not significantly different) rates of growth. Yet, unlike the other language and literacy skills that could all be characterized by the same model of development (sigmoidal) across groups, the late self-regulation developers' vocabulary development was better approximated by linear growth. A conclusion that late self-regulation developers show a different shape of vocabulary development when compared to the other groups warrants caution, but is in line with the inconsistent relations observed between vocabulary and self-regulation in other work (Cameron Ponitz et al., 2009; Fuhs et al., 2014; Matthews et al., 2009; McClelland et al., 2007; Wanless et al., 2016).

Educational Implications

Results from this study are consistent with the idea that augmenting children's ability to manage their own behaviors as early as possible would benefit children's language and literacy performance during their first years in school and perhaps allow them to engage in earlier development of these skills, although we acknowledge that our results do not provide causal evidence. There are likely biological constraints that restrict the degree to which children can control their behaviors independently (Clark et al., 2016; Posner & Rothbart, 2000), given that multiple trajectories of self-regulatory development have been observed among several community samples within the United States (BLINDED) as well as in other countries (Wanless et al., 2016). However, although some variation in self-regulation development is normative, supporting it intentionally as early as preschool would likely reap benefits for children's language and literacy achievement.

Simply being in preschool does not appear to boost children's self-regulatory capabilities (Skibbe, Connor, Morrison, & Jewkes, 2011), so it is important to consider other directions that might support early development in this area. Children's behavioral self-regulation can be improved through the use of small therapeutic playgroups implemented by teachers for children who are at-risk for poor behavioral or academic outcomes (Pears et al, 2007; Schmitt et al., 2015). In addition to direct interventions, there are a variety of contextual

supports that educators can utilize to help children to manage their own behaviors more effectively. Teachers should first be aware that certain settings are more likely to tax children's self-regulatory abilities (e.g., whole group activities) than others (e.g., small group activities) and then provide additional reinforcement in more challenging situations (Rimm-Kaufman, La Paro, Downer, & Pianta, 2005). Furthermore, classrooms characterized as having more disruptions and less instructional time (e.g., greater transitions between activities) were more likely to have children with lower levels of self-regulation (Day, Connor, & McClelland, 2015). Not surprisingly, children in these classrooms also gained fewer literacy skills than peers in classroom that were better organized. More organized classrooms have also related to greater growth for children with weaker behavioral self-regulation (Connor et al., 2010). Thus, researchers should not just consider whether children themselves are ready for school, but whether teachers are prepared to deal with the different self-regulatory capacities that children bring with them to school.

Limitations

Several limitations should be considered as part of the present work. Our sample was relatively advantaged and homogenous in terms of ethnicity, average household income, and maternal education. Living in a low-income household can place a strain on a child's self-regulatory development (Blair & Raver, 2012; Raver, 2004). Thus, the development of behavioral self-regulation reported in the current study may be earlier and/or greater than that seen in other populations, although there is no reason to expect that socioeconomic status would impact the relation between self-regulation and language and literacy outcomes. The results are consistent with previous findings for self-regulation (Wanless et al., 2016), and links between the development of executive function and academic achievement in more disadvantaged samples (Sektnan et al., 2010; Willoughby et al., 2016). In addition, other child factors that are related to self-regulation, such as child IQ (Calero, García-Martín, Jiménez, Kazén, & Araque, 2007), may help to explain some of the observed group differences in language and literacy achievement. Unpacking the underlying reasons for the relations between self-regulation and language and literacy achievement is an important area for future research.

Although the self-regulation measure we used in the present work (HTKS) is widely used and highly regarded (e.g., Allan & Lonigan, 2014; Cameron et al., 2009; McClelland et al., 2014), it does not capture all aspects of self-regulation, as it focuses on behavioral self-regulation globally rather than specific aspects of executive function. It is possible that one of the components of self-regulation captured by the HTKS (working memory, attention) may explain differences in literacy growth more directly. However, capturing self-regulation in a way that integrates applicable skills may be more relevant than measures which capture only one aspect of self-regulation; findings consistently indicate that the HTKS as a measure of multiple skills is more strongly associated with elements of academic achievement, including literacy, than other measures (McClelland et al., 2014).

Conclusion

By investigating how children's language and literacy skills develop, we are able to assert that developing behavioral self-regulation earlier has consistent and enduring implications

for children. As states direct their attention towards core standards and achievement scores designed to help students to become prepared for college (Achieve, 2014), it is important to remember that academic skills develop in concert with self-regulation. Such considerations may be even more important for children at-risk for underachievement, as it has been argued that self-regulation is a key factor for improving academic outcomes for children living in poverty (Raver, 2012). Furthermore, children with lower self-regulation are more likely to be retained a grade than students with higher regulatory capabilities, even when literacy scores are fairly comparable (Dombek & Connor, 2012). Thus, educators and policymakers should consider children's behavioral self-regulation when creating learning environments for students, as students who master these skills earlier are advantaged with regards to their language and literacy development from preschool through second grade.

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Highlights

- The trajectory of self-regulation development was associated with children's language and literacy skills throughout preschool and thru second grade.
- Children who developed self-regulation earlier had both higher levels and earlier development of both decoding and reading comprehension, although the rate of development was not faster.
- Children with early self-regulation trajectories developed phonological awareness earlier than those with late self-regulation trajectories.
- Children with early self-regulation trajectories had higher levels of vocabulary than children with intermediate trajectories, but did not differ on the rate or timing of vocabulary development.

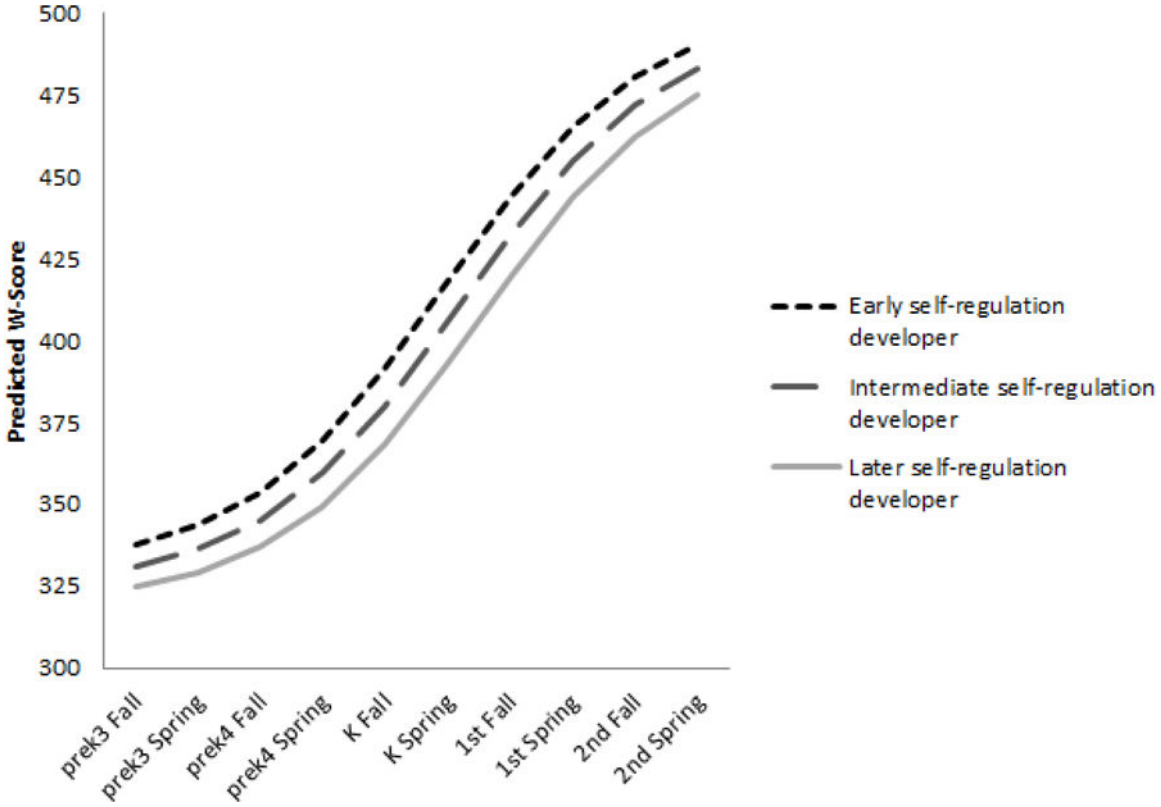

Figure 1.
Letter Word Identification trajectories by children's predicted self-regulation developmental trajectory classification.

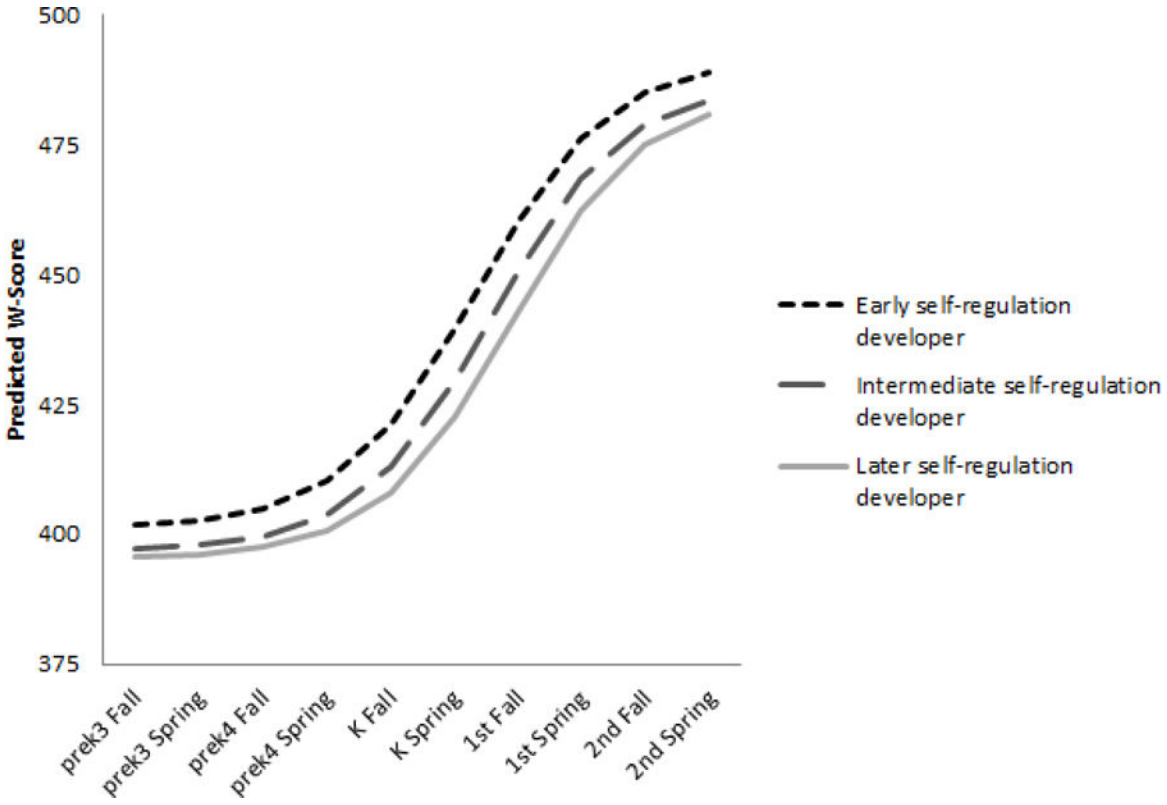

Figure 2.

Passage Comprehension trajectories by children's predicted self-regulation developmental trajectory classification.

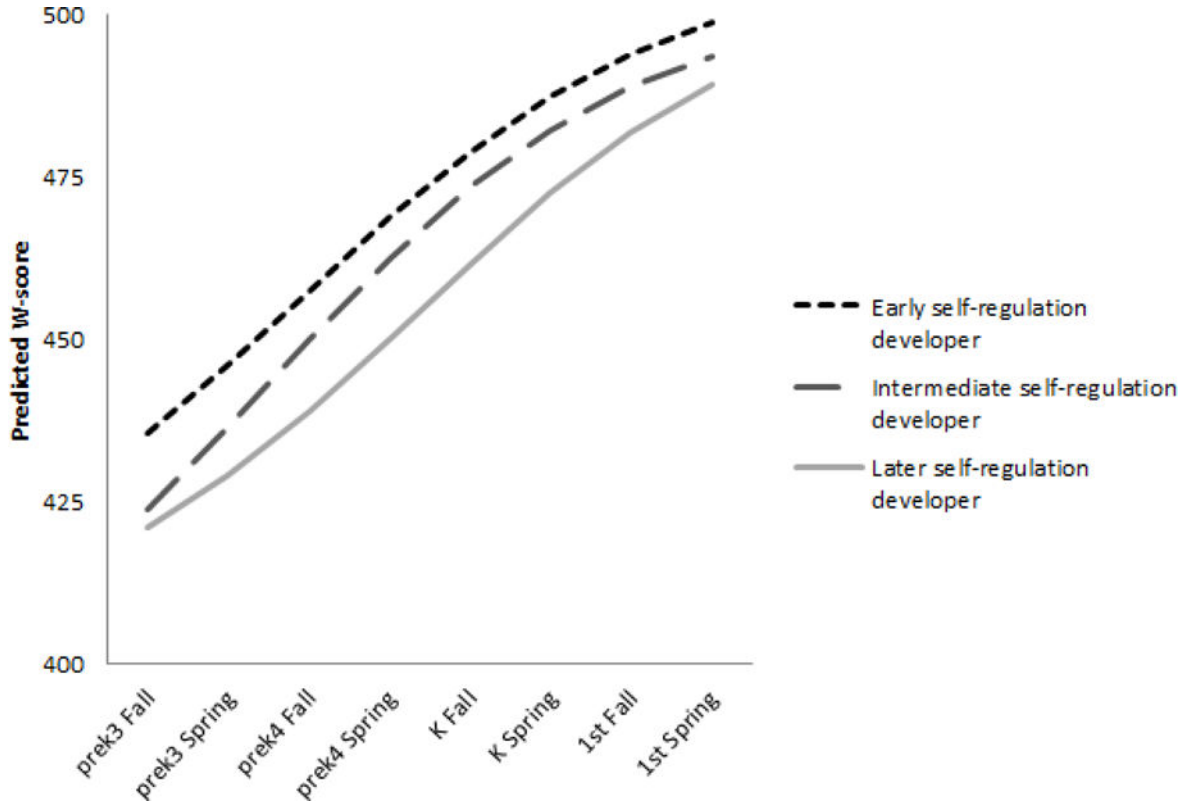

Figure 3.

Sound Awareness trajectories by children's predicted self-regulation developmental trajectory classification.

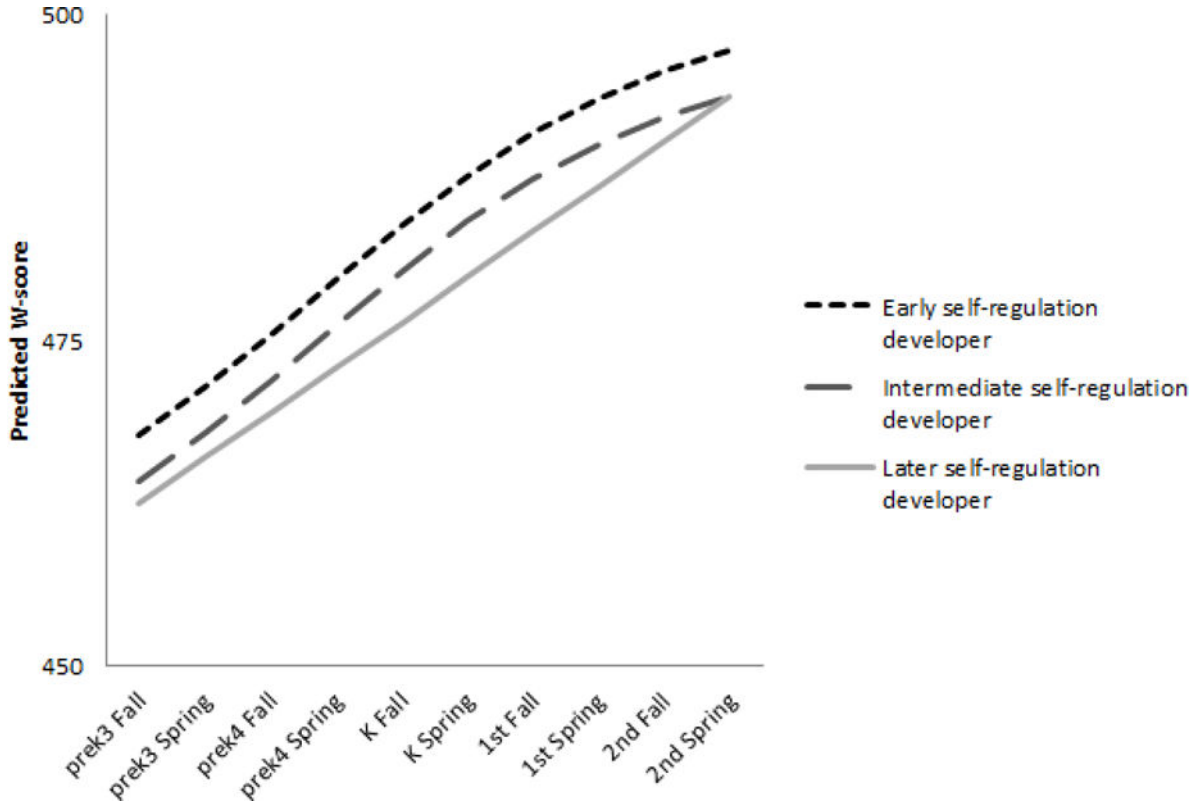

Figure 4.
Vocabulary trajectories by children's predicted self-regulation developmental trajectory classification.

Table 1

Children's Fall and Spring W Scores on the Woodcock-Johnson Tests of Achievement

Measure	Grade	n	Fall M (SD)	n	Spring M (SD)
Self-regulation	Preschool, Year 1	190	14.15 (15.70)	189	19.68 (16.41)
	Preschool, Year 2	302	17.31 (14.89)	293	23.59 (14.15)
	Kindergarten	281	28.44 (11.88)	275	33.09 (9.32)
	First grade	217	33.72 (7.55)	218	35.20 (6.59)
	Second grade	–		–	
Letter-Word Identification	Preschool, Year 1	199	322.82 (25.14)	193	339.38 (23.91)
	Preschool, Year 2	314	345.41 (24.59)	310	360.78 (27.36)
	Kindergarten	284	375.02 (29.11)	280	405.50 (29.69)
	First grade	256	428.55 (30.27)	205	456.27 (26.67)
	Second grade	90	471.87 (26.09)	88	482.39 (22.61)
Passage Comprehension	Preschool, Year 1	120	392.45 (17.64)	165	399.58 (15.72)
	Preschool, Year 2	299	400.84 (15.30)	310	405.52 (18.08)
	Kindergarten	284	410.52 (21.83)	280	431.47 (25.90)
	First grade	256	449.88 (22.66)	205	468.64 (15.39)
	Second grade	90	478.99 (13.69)	88	485.50 (13.52)
Picture Vocabulary	Preschool, Year 1	198	463.14 (15.05)	194	468.65 (12.08)
	Preschool, Year 2	314	471.74 (12.67)	310	476.35 (11.52)
	Kindergarten	284	478.61 (11.47)	280	484.70 (10.21)
	First grade	256	486.43 (9.84)	205	489.82 (10.31)
	Second grade	90	494.71 (8.91)	88	494.23 (9.00)
Sound	Preschool, Year 1	198	428.56 (13.81)	194	441.01 (17.56)
Awareness	Preschool, Year 2	314	447.03 (18.05)	310	460.75 (16.85)
	Kindergarten	284	469.21 (14.51)	280	480.51 (12.42)
	First grade	255	487.14 (11.14)	205	493.30 (12.49)
	Second grade	–		–	

Table 2

Summary of Literacy Models

	Letter Word Identification AIC/aBIC	Passage Comprehension	Sound Awareness	Picture Vocabulary
All free	18892.94/18924.60	17619.58/17650.99	**15710.50/15725.60**	15921.07/15952.05
Level constrained	18901.74/18930.65	17626.84/17655.51	15719.45/15733.22	15920.66/15950.95
Slope constrained	**18886.29/18915.20**	**17611.96/17640.63**	15718.74/15732.5	15919.93/15950.22
Inflection constrained	18898.79/18929.09	17633.13/17663.17	15741.20/15755.02	15919.09/15949.38
Level and slope constrained	18895.47/18921.63	17620.77/17646.71	15718.73/15731.12	15918.81/15948.41
Level and inflection constrained	18931.69/18959.22	17671.71/17699.02	no convergence	no convergence
Slope and inflection constrained	18893.22/18920.76	17626.75/17654.06	15743.67/15756.06	**15918.65/15948.26**
All constrained	18924.41/18949.20	17664.48/17689.06	15804.25/15815.27	15926.50/15955.41

Table 3

Planned Comparisons between Self-regulation Groups

	Letter Word Identification			Passage Comprehension			Sound Awareness			Picture Vocabulary		
	AIC/ aBIC	**Wald test (df)**	***p*-value**	**AIC/ BIC**	**Wald test (df)**	***p*-value**	**AIC/ aBIC**	**Wald test (df)**	***p*-value**	**AIC/ aBIC**	**Wald test (df)**	***p*-value**
All free	**18892.94/18924.60**	–	–	**17619.58/17650.99**	–	–	**15710.50/15725.60**	–	–	**15921.07/15952.05**	–	–
Early and intermediate developers equal	18900.90/18930.50	13.74 (2)	<.01	17634.24/17663.60	21.17 (2)	<.001	15724.42/15737.50	19.25 (3)	<.001	15926.50/16088.65	10.05 (1)	<.01
Intermediate and late developers equal	18899.80/18929.40	12.34 (2)	<.01	17626.80/17656.16	13.41 (2)	<.01	15777.17/15790.25	78.34 (3)	<.001	–	–	–

Table 4

Final Model Parameters

	Mean Level	Mean Slope	Grade at Point of Maximal Growth
Letter Word Identification			
• Early	416.85	27.01[a]	5.96
• Intermediate	411.20	27.01[a]	6.21
• Late	406.10	27.01[a]	6.41
Passage Comprehension			
• Early	446.38	21.53[b]	6.32
• Intermediate	441.92	21.53[b]	6.59
• Late	440.30	21.53[b]	6.87
Sound Awareness			
• Early	456.13	11.51	2.88
• Intermediate	441.90	13.42	2.40
• Late	454.20	11.59	4.36
Picture Vocabulary			
• Early	477.96	4.27[c]	3.59[d]
• Intermediate	474.44	4.27[c]	3.59[d]
• Late (linear)	459.04	3.48	–

Note. The point of maximal growth references the measurement occasion (fall/spring) of each grade when the group reached their greatest growth. Measurement occasions range from 1 = fall of the first year of preschool to 10 = spring of second grade. Parameters with the same superscript were constrained equal.