Running Head: Predicting Precocious Reading

The Product, Process, and Prediction of Precocious Reading

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While most children require formal instruction to begin reading, some children learn to read before beginning schooling and without receiving explicit home instruction (Jackson, 1988). This ability, while related to IQ, is not fully explained by measures of intelligence or language precocity (Crain-Thoreson & Dale, 1992; Jackson & Myers, 1982). This suggests that advantages in other cognitive skills, such as working memory or phonological awareness, environmental factors, such as the emphasis on literacy in the home, or biological factors, such as genetics or neural processes, may explain considerable variance in early reading acquisition. Understanding the basis for precocious reading is important for those who study giftedness, cognitive development, and reading, as well as for parents hoping to help their children succeed in reading (Jackson, 1992). In this paper, I will review research showing the longitudinal outcomes of precocious readers, a theoretical model of precocious reading, and predictors that distinguish among precocious readers and their non-reading peers with similar cognitive abilities. I will conclude with a suggested battery of assessments for predicting precocious reading and questions to be addressed by future research.

What is precocious reading?

Definitions of precocious readers have varied across studies and eras, and there is no set "standard deviation" beyond which a child's reading is considered precocious (Jackson & Coltheart, 2001). Recent studies have tended to define precocious readers as those who read words accurately at the second grade level or above before beginning first grade. At ages 2-4, a child's reading may be considered precocious if it reaches first grade levels of accuracy (Jackson & Coltheart, 2001). It is important to note that this definition is based on oral reading fluency, which is just one of the five essential components of reading listed by the National Reading

Panel (2000). Precocious readers have necessarily acquired alphabet knowledge before reading (Jackson, 1988), but they may not have equally exceptional phonemic awareness, vocabulary skills, or comprehension. Indeed, one special group of precocious readers, children with *hyperlexia*, show precocious oral reading but have below average verbal and cognitive abilities and low comprehension scores (Healy, 1982). While many studies have included children regardless of educational experience, intensive reading instruction has not been a typical experience for precocious readers (Jackson, Donaldson, & Cleland, 1988; Jackson, Donaldson, & Mills, 1993).

The Product: Longitudinal outcomes of precocious readers

When considering reading precocity, which is an important individual difference in early childhood, it is useful to frame our discussion in terms of both the short- and long-term consequences of early reading. While most investigations of precocious reading have focused on comparing young precocious readers with their age-matched and reading-level-matched intellectual peers, several researchers have followed these readers through elementary school to determine the long-term effects of a head start in reading. Durkin (1966) compared her precocious readers to classmates matched for IQ in each grade, finding that children who read early continue to outperform non-early-reading peers on tests of reading achievement through 6th grade. These results were found even when excluding the children who had been double-promoted (skipped a grade) from the sample of early readers, and as these children were likely the brightest students in the group, the findings are that much more convincing. However, as Jackson (1988) points out, the relationship between early reading and later reading achievement has not been shown to be causal; certain factors, such as parent involvement or specific intellectual abilities, may be implicated. Mills and Jackson (1990) showed that children's verbal

ability at 5-6 years predicted individual differences in precocious readers' later reading comprehension as well as or better than initial reading skills did.

Jackson and Kearney (1995) argue that precocious reading predicts good, but not necessarily excellent, performance in English in later years, and show that highly intelligent children who are not precocious readers demonstrate similar intellectual achievement by the 6th grade. Similarly, Stainthorp and Hughes (2004) charted the gap in reading skills between precocious readers and their intellectually matched, non-precocious reading peers and found that the gap begins to narrow by age 11. One problem with studies using existing reading achievement data, however, is that there may be ceiling effects in the data – standardized tests may only allow readers to demonstrate a certain level of proficiency, masking true performance differences between subgroups of intellectually advanced students. Thus, it is unclear if precocious readers' acquisition of reading skills slows down over the course of elementary school or if we have simply failed to properly assesses high-level reading. While this remains an open question, it should be noted that research has not demonstrated any long-term academic benefits conferred by precocious reading.

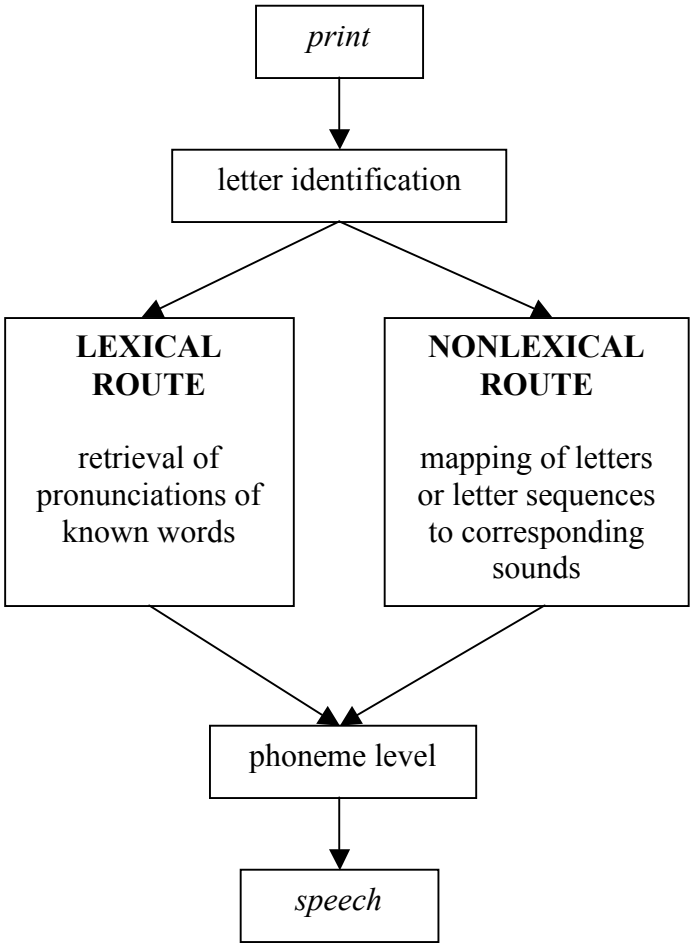
The process: how precocious readers read

A number of conflicting findings and descriptive studies showing vastly different skill sets in precocious readers have led to the general conclusion that, just as struggling readers can struggle for a number of reasons, precocious readers may have a variety of skills that facilitate their reading acquisition (Jackson & Coltheart, 2001). Precocious readers have been shown to have substantial variation in decoding skills: some precocious readers can decode any word, even if it requires the use of complex rules (Backman, 1983), but on average, precocious readers are

more advanced in their ability to read text than individual words (Jackson & Biemiller, 1985) and to recognize familiar words than to decode new words (Jackson et al., 1988).

Jackson and Coltheart (2001) describe a dual-route model of oral word reading that accounts for the advanced oral reading ability of precocious readers who have and have not developed strong decoding skills and phonological awareness (see Box 1). In this model, once readers have identified the letters that comprise a word, they may retrieve the pronunciation from memory or use letter-sound correspondences to pronounce it. While these processes are separable in laboratory tasks, the authors propose that they are not independent and that some precocious readers may be especially adept at switching between the routes, while others may have developed strong lexical abilities to compensate for weaker non-lexical (decoding) skills. Fletcher-Flinn and Thompson (2004), in their follow-up study of Maxine (an extraordinarily precocious reader first described by these authors in 2000), showed that by age 7, her word reading was equivalent to that of a 16-year-old and her spelling was equivalent to that of a 15-year-old, while her phoneme segmentation abilities were equivalent to those of a typical 5-year-old. To explain Maxine's ability to spell in the face of her poor phonemic awareness, the authors proposed that she used "implicit lexicalized phonological recoding", a process whereby she would turn graphemes into phonemes based on her knowledge of the grapho-phonemic correspondences of other words in her lexicon. Essentially, they argued that she was using her strong lexical route to bootstrap her non-lexical processing, so that as her lexicon became stronger so did her implicit knowledge of phonics. At the same time, they showed that her greatest skill was in using the lexical route, showing that she had strong lexical orthographic representations linked to meaning and accessed independently of phonology by reporting her superior performance on a task where she had to assess the meaningfulness of sentences like

Box 1. A dual route model of oral word reading (adapted from Jackson & Coltheart, 2001).



Note that the lexical and nonlexical routes have the same initial stage (letter identification) and the same final stage (phoneme activation) and therefore cannot be considered independent. Some processing is common to both paths (e.g., the reading of regular words), while other tasks use one or the other. Pronouncing irregular words (e.g., would, was) requires the retrieval of the word from the mental lexicon, because these words violate the grapho-phonemic code used in the nonlexical route. Pronouncing pseudowords (e.g., fleep, fean) requires using letter-sound correspondences because the words cannot be retrieved from memory. Research by Backman (1983) suggests that all precocious readers excel at using the lexical route, but only some demonstrate facility at using the nonlexical route. Research by Jackson, Donaldson, and Cleland (1988) has shown that both Decoding Rule Use and general reading precocity predict children's performance on pseudoword reading tasks, suggesting that high reading ability does not account for all of the variance in sounding out words.

"The son is shining in the sky" quite quickly. Readers relying on non-lexical routes are more likely to judge such a sentence as making sense, based on the sound and not the spelling of the word "son".

The dual-route model of oral reading applies to all readers, regardless of precocity. The standard course of reading development builds upon readers' non-lexical skills to build the lexicon and strengthen the lexical route: readers who begin reading by using non-lexical routes are theorized to build their lexicons by sounding out words and storing the pronunciation of that letter string in long-term memory for later automatic retrieval.

The predictors of reading precocity

Phonological awareness

Quite a bit of research has examined the role of phonological awareness in reading precocity, because phonological awareness skills are fundamental to the development of decoding abilities in typical readers. Initial findings were mixed, with some researchers (e.g., Patel & Patterson, 1982) concluding that precocious readers had bad metalinguistic skills, while other researchers were finding that precocious readers were quite adept at tasks involving the manipulation and deletion of phonemes (e.g., Backman, 1983). Two considerations clarify this situation: first, studies of precocious readers often have small sample sizes (Jackson, 1992); Patel and Patterson studied 20 precocious readers, while Backman studied 24; second, as expressed in the dual-route model explained above, some readers may make more use of the nonlexical route than others. Indeed, Backman found that while their 24 precocious kindergarten readers read pseudowords (nonsense words, such as zat) as well as their reading-level-matched second grade sample and on average read pseudowords as well as regular words, there was a specific subgroup of 7 precocious readers who could not do the sound deletion task and who were also substantially

poorer at pseudoword reading and spelling. Jackson and Coltheart (2001) have argued that evaluating the predictive power of phonemic awareness across the group of precocious readers may lead to incorrect conclusions, and that this association should be examined within specific subgroups of precocious readers. To date, there have not been studies that have answered this challenge. The data seem to indicate that strong phonemic awareness skills can facilitate reading, but that weak phonemic awareness does not necessarily impede reading development in certain groups of readers.

Rapid automatic naming

Precocious reading achievement has been consistently associated with the ability to name letters rapidly, compared with intelligence- and age-matched non-reading peers who also have mastered the alphabet (Jackson & Myers, 1982; Jackson et al., 1988). This task may be measuring a more general ability to efficiently retrieve information from memory (Jackson, 1988), which maps on well to precocious readers' efficient use of the lexical route. Latent factor analysis has revealed word and text reading speed to be important components of precocious reading ability as well (Jackson et al., 1998). Jackson and Biemiller (1985) compared the letter-, word-, and text-reading speed of precocious kindergarten readers to the speeds of 2nd and 3rd grade students matched for intelligence and reading level, and found that the kindergarteners were slower at naming letters, about the same at reading word lists, and faster at reading text than the 2nd and 3rd grade typically developing readers. They concluded that precocious readers are particularly efficient at interpreting sentence-level text, speculating that perhaps precocious reading relies more heavily upon context facilitation. Jackson and Donaldson (1989) attempted to test this hypothesis by measuring children's latency to reading a target word presented after facilitating, neutral, or misleading context, but found that precocious

kindergarten readers used less contextual facilitation than older readers. They have suggested that while precocious readers may have learned that text reading is most enjoyable and comprehensible while reading quickly, they may set very stringent word-identification criteria when the task is narrow and reading can be easily slowed down to improve accuracy. In this view, it is the precocious readers' ability to shift strategies to match the needs of the task that confounds these results. Again, this interpretation is speculative; examination of perfectionist tendencies in word-naming tasks may shed some light on the situation. What has been established in a predictive sense is that very young precocious readers name letters more quickly than their peers.

Oral language skills

Jackson and Coltheart (2001) have argued that the very existence of children with hyperlexia should serve as proof that strong verbal abilities are not necessary for the development of precocious reading, as hyperlexia is defined by pathological cognitive or language development concurrent with precocious reading ability. Early talkers are not especially likely to become precocious readers either. In Crain-Thoreson and Dale's (1992) prospective study of 25 verbally precocious toddlers, only 1 child became a precocious reader. This incidence rate, 4%, is quite similar to the estimated population incidence of 1-3% (Durkin, 1966; Jackson, 1988), although of course this is an insufficient sample to draw firm conclusions. Work detailing the development and skills of bilingual precocious readers of English has made particularly clear that oral reading fluency can develop quite early, even in children for whom English is not spoken at home and whose comprehension lags substantially behind. Skill profiles of 12 bilingual precocious readers has shown that while these children are 1.4 standard deviations lower than their monolingual counterparts on accuracy in reading cloze passages, they

are 0.3 standard deviations higher on the Matching Familiar Figures Test, 0.2 standard deviations higher on the letter naming speed, 0.4 standard deviations higher on orthographic mapping speed, and 0.2 standard deviations higher on word naming speed (Jackson & Lu, 1992). Precocious reading in bilingual children seems to involve retrieving lexical information quite quickly from memory and discriminating visual stimuli rapidly, as opposed to having strong oral language skills. Thus, while advanced oral language skills may be helpful in developing early reading skills, they are not necessary for the development of precocious reading.

Other cognitive skills

In multiple studies by Jackson and her colleagues (Jackson & Myers, 1982; Jackson et al., 1988), precocious readers have outperformed age- and intelligence-matched peers on tests of forward and backward digit span, suggesting that working memory skills play a role in the development of precocious reading. Jackson (1992) has suggested that this result may be due to precocious readers' ability to create and "read" a mental image of the series of digits they have heard as a result of their greater reading experience, but notes that parents of precocious readers often discuss their children's remarkable ability to remember long strings of information. Jackson et al. (1993) found that precocious kindergarten readers performed more like reading-level-matched second graders than like age- and intelligence-matched peers on a test of reflectivity, where children are shown one figure (e.g., a tree) and then six variants of the same picture, only one of which is an exact match. Precocious readers were more likely to respond accurately than other kindergarteners, who tended to answer more quickly and inaccurately. This finding, while suggestive, needs replication.

Finally, the role of IQ has been discussed at length in terms of precocious reading. While the mean IQ scores of precocious readers are above average – about 130, measured at age 5 or 6

(Backman, 1983; Jackson, 1992; Jackson et al., 1993), not all precocious readers are above average; indeed, some are below (Durkin, 1966; Jackson et al., 1988). Children with hyperlexia may have below-average intelligence while showing phenomenal ability to break the phonetic code (Healy, 1982). Among preschoolers with above-average intelligence, Jackson and Myers (1982) found that those with the very highest IQs were not more likely than the others to be precocious readers. Further evidence that high IQs don't guarantee precocious reading comes from the work of Terman – only half of his longitudinal study participants were reading by age 5 (Jackson, 1998). Therefore, having a high IQ appears to be neither a necessary nor sufficient condition for precocious reading.

The home environment

Studies of parental support for reading are conclusive: a strong home literacy environment is a necessary but not sufficient condition for precocious reading. Durkin (1966) found that parents of precocious readers tended to have higher than average socio-economic status and tended to spend more time reading to children than did other parents; Jackson et al. (1988) asked the same home literacy questions of parents of precocious readers and found that nearly all parents reported talking to their children about stories, letters and words, the sounds of letters, numbers, and spelling, and reported that these discussions were child-initiated and not parent-driven. Thomas (1984) asked parents of 4-year-old precocious readers and intellectually-matched nonreaders about family literacy activities and related background variables, and found no differences in parental educational attainment, marital history, occupation, number of hours that the mothers worked outside the home, the amount of time spent with the child, the number of books read to the child, the number of magazine subscriptions, or the amount of television watched. Stainthorp and Hughes (2000) similarly found no differences in the home literacy

environments of precocious and non-readers who were matched on socio-economic status and receptive vocabulary scores. For children to read precociously, they must have access to print, but providing this access does not guarantee precocious reading.

Child interests

Jackson (1988) describes precocious readers as notably interested in print, compared with age-matched nonreaders. Parental report of children's toy preferences indicates that precocious readers are more interested in print-related toys and games at ages 2, 3, and 4, while non-readers are more interested in gross-motor toys and fantasy toys at these ages (Thomas, 1984). Thus, a good predictor of a child's precocious reading ability may be his or her attraction to books and print-related toys in early childhood.

Instructional effects

Preschool instruction does not seem to be a factor in precocious reading in kindergarten (Jackson, 1988). Furthermore, interventions to create precocious readers have generally been unsuccessful (Jackson & Coltheart, 2001). Durkin (1974) randomly assigned some students to receive reading instruction in preschool and kindergarten while others began reading instruction in first grade. By third grade, the intervention group no longer showed an advantage over the others, suggesting little benefit as a result of a head start in reading instruction. Precocious advancement beyond basic letter and sight-word recognition in early literacy training programs "may depend on fortuitous juxtaposition of individual aptitudes and interests with well-timed facilitating experiences" (Jackson, 1988, p. 203).

Biological factors

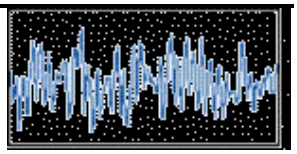
In a multinational twin study of genetic, shared environment, and non-shared environmental influences on development, Byrne et al. (2006) showed that 61-63% of the

variance in preschool and kindergarten phonemic awareness was due to genetic factors, while 28-30% was due to shared environment and approximately 10% was due to nonshared environmental factors. Similarly, 60-64% of rapid naming variance was due to genetic factors, while approximately 25% of this variance was due to nonshared environment. In preschool, genetic factors accounted for 57% of the variance in verbal memory, while shared environment accounted for another 29% of the variance. In kindergarten, 70% of the variance in word reading was attributed to genetic factors, while 22% of the variance was accounted for by shared environment. In contrast, verbal ability, vocabulary, and grammar acquisition were largely accounted for by shared environment. A discussion of the limitations of comparisons of monozygotic and dizygotic twins for establishing genetic and environmental contributions is beyond the scope of this paper; even a cautious interpretation of these findings that twins who share 100% of their genes are substantially more similar in rapid naming skills, verbal memory, and word reading than those who share on average 50% of their genes suggests that there is a genetic component to the skills that best predict precocious reading. As Jackson and Coltheart (2001) point out, research has shown for over a century that reading difficulties run in families; it is not implausible that reading exceptionalities would run in families as well.

Another fascinating indicator of biological differences between precocious readers and age- and intellect-matched nonreaders comes from a quantitative EEG study by Suldo, Olson, and Evans (2001). They report that previous research on developmental changes in brain wave activity has suggested that as children's brains mature, the peak frequency in alpha waves increases to about 10 Hz., similar to that of adults; additionally, prior research has reported declines in alpha peak frequency in those and reading difficulties. Quantitative EEG data from precocious readers, age- and ability-matched peers, and reading-level-matched peers (see Box 2)

Box 2. Using Quantitative Electroencephalogram (QEEG) data to distinguish among precocious and typical readers of equivalent general intelligence.

- An electroencephalogram (EEG) is a recording of the brain's electrical activity.
  - The brain produces small electrical signals which the EEG machine is able to pick up and reproduce as a record on paper or on a computer screen.
  - The EEG recording shows rhythmical electrical activity, often called brain waves.
- The child sits in a comfortable chair throughout the procedure.
- The technologist measures the head and marks electrode sites.
- The technologist applies a sticky cream and a certain number of small metal disc electrodes onto the scalp, holding them in place with tape or a net.
- The child is instructed to sit as still as possible, relaxing with eyes closed.
- The technologist observes the EEG via computer monitor and gives instructions until eye and other movement artifacts are minimized.
- Three four-minute samples of brain activity are collected.
- The sample with the largest number of epochs is used for data analysis.



Alpha waves

A child ready for EEG testing

Research Findings

Suldo, Olson, & Evans (2001) compared peak frequency in the alpha band (8.0 to 12.0 Hz) of 15 children with precocious reading ability (ER) to that of 15 age-level matched (ALM) controls and 15 reading-level matched (RLM) controls who were 2.5 years older. Children in both control groups had intelligence scores that matched those of children in the ER group. Quantitative EEG (QEEG) data were obtained from 19 scalp electrode sites. Peak frequency in alpha differentiated the groups. The ER group had significantly higher alpha peak frequency (means between 9.0 and 9.3 Hz) than the ALM group (means between 8.6 and 8.8 Hz) at 16 of the 19 electrode sites examined. The alpha peak frequency of the RLM group did not differ significantly from that of the ER group. Suldo et al. (2001) suggest that precocious readers may have advanced brain maturation.

TABLE 1. Mean Peak Frequency of Alpha Band in Early Readers, Age Matched Controls, and Reading-Level Matched Controls

	Early Readers		Age Matched		Reading-Level Matched	
Site	M	(SD)	M	(SD)	M	(SD)
F1	9.16	(.35)**	8.73	(.37)**	9.28	(.33)
F2	9.15	(.38)*	8.80	(.42)*	9.25	(.33)
F7	9.22	(.37)**	8.81	(.33)**	9.34	(.31)
F8	9.21	(.44)*	8.84	(.36)*	9.31	(.33)
F3	9.13	(.43)*	8.77	(.43)*	9.21	(.35)
F4	9.13	(.40)*	8.76	(.42)*	9.23	(.32)
T3	9.24	(.45)*	8.84	(.36)*	9.42	(.48)
T4	9.17	(.56)*	8.80	(.37)*	9.36	(.40)
C3	9.29	(.51)**	8.83	(.40)**	9.38	(.44)
C4	9.20	(.56)	8.87	(.41)	9.43	(.44)
T5	9.10	(.58)*	8.69	(.42)*	9.37	(.43)
T6	9.07	(.59)*	8.69	(.36)*	9.33	(.51)
P3	9.08	(.53)*	8.66	(.38)*	9.27	(.43)
P4	9.04	(.57)*	8.64	(.34)*	9.28	(.38)
O1	9.10	(.62)*	8.65	(.38)*	9.39	(.31)
O2	9.02	(.58)	8.69	(.38)	9.36	(.42)
FZ	9.09	(.48)*	8.74	(.41)*	9.15	(.37)
CZ	9.02	(.50)	8.72	(.36)	9.16	(.44)
PZ	9.09	(.52)*	8.64	(.37)*	9.27	(.45)

Note 1. For statistical comparisons between the ER and AM samples, * $p < .05$, ** $p < .01$ (LSD tests for independent samples).
Note 2. For statistical comparisons between the ER and RLM samples, $p > .05$ at all sites.
Note 3. For statistical comparisons between the AM and RLM samples, $p < .01$ at all sites.

suggests that precocious readers may have greater brain maturity than non-readers, and shows that they have alpha peak frequencies indistinguishable from those of older children with similar reading skills. This raises a number of interesting questions about the relationship between brain wave activity and reading activity, including the directionality of the relationship (is reading driving brain maturity or is brain maturity allowing for superior reading?) and the predictive power of EEG tests to distinguish precocious readers from other bright children.

The prediction of precocious reading

A goal of this paper is to suggest a battery of assessments that could be used to determine whether or not young children are likely to read precociously, based on research tasks that have successfully discriminated precocious readers from non-readers of similar intellectual ability. As has been addressed in the previous section, assessments of IQ, phonemic awareness, oral language, and home literacy environment are not likely to have tremendous predictive power – access to print and print-related concepts at home is necessary for the development of reading but not sufficient, and IQ, phonemic awareness, and strong oral language skills are neither necessary nor sufficient for precocious reading. There does seem to be a genetic basis for reading ability, but we have not yet developed the methods for widespread genetic testing for complex cognitive skills.

Assessments likely to carry the most predictive power are those on which precocious readers perform similarly to reading-level-matched peers and unlike age- and cognitive ability-matched peers. From the research reviewed above, we should assess:

- Alpha peak frequency using EEG testing (see Box 2)
- Digit span, using the Weschler Intelligence Scale for Children – Revised (WISC-R; Weschler, 1974)

- Letter-naming, word-naming, and text-reading speed using the Biemiller Test of Reading Processes (Biemiller, 1981)
- Reflectivity using a revised version of the Matching Familiar Figures Test (Cairns & Cammock, 1978)

All of these measures should be positively associated with the likelihood of precocious reading. What remains to be determined is whether these measures can be used with young children *before* the emergence of precocious reading, or whether differences in these skills are only found after precocious reading emerges. There is currently no research that has accurately predicted the development of precocious reading from child or family characteristics measured in infancy and toddlerhood; it is unclear whether this is because it cannot be predicted from skills we can measure in very young children or whether we have simply not tried the right assessments.

Conclusions

Precocious reading is a fascinating phenomenon both for its own sake and also as it highlights various individual and group differences in reading development. There has not been as much research on children who read exceptionally well as there is on children who struggle with reading; therefore, there are many open questions (see Box 3). One of the most important of these questions is how to predict the emergence of precocious reading, particularly as parents focus increasingly on preparing children for school success. Researchers have cautioned that too much early instruction in reading skills may not promote the development of positive attitudes toward reading (Backman, 1983), and have shown that the gains from early literacy instruction in preschool and kindergarten are erased by the third grade (Durkin, 1974). Still, for some children, early guidance in basic reading skills may help precocious reading develop (Jackson, 1988).

Understanding for whom early intervention is useful will help parents and teachers provide optimal learning environments for all children.

Box 3. Questions for future research.

- At what point does comprehension catch up to fluency for the average precocious reader?
- Do readers skilled at using the lexical path benefit from instruction in phonics?
- Can very early training in associated cognitive skills (working memory, reflectivity) help children learn to read more quickly?
- What is the directionality of the relationship between brain maturation?
    - Does early brain maturation promote precocious reading?
    - Does the process of reading help the brain mature?
    - Is the relationship between brain maturation and reading development bi-directional?
    - Can neurotherapy interventions with biofeedback increase brain patterns that promote reading?
- Which predictors of precocious reading are associated with strong use of the lexical and non-lexical routes?
- How do the relationships between these predictors of precocious reading and reading achievement change when children from a wide range of reading and cognitive skills are included?
- Can we predict precocious reading from assessments of cognitive skills at ages 2, 3, and 4?
- How does our understanding of precocious reading change when we analyze the development of readers who primarily use the lexical route and readers who use both routes separately?

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