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Literacy environment and the development of children's cognitive skills

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Early literacy development: Matthew effects

The role played by experiential factors in determining variation in children's cognitive growth has been at the heart of much theorizing in developmental psychology. Multiple factors have been cited as contributing to children's cognitive development. For example, individual differences in home and family environment are hypothesized to play a large role in children's cognitive growth (e.g. Hewison and Tizard, 1980; Alwin and Thornton, 1984; Hess *et al.*, 1984; Iverson and Walberg, 1984).

When speculating about variables in people's ecologies, which could account for cognitive variability, in an attempt to supplement purely genetic accounts of mental ability (e.g. Ceci, 1990), we should focus on variables that have the requisite potency to perform their theoretical roles. A class of variable that might have such potency would be one that has long-term effects because of its repetitive and/or cumulative action. Schooling is obviously one such variable (Morrison, 1987; Cahan and Cohen, 1989; Ceci, 1990, 1991). In this chapter we shall argue that another experiential factor which, like schooling, has long-term cumulative effects is exposure to print.

Reading is a very special type of interface with the environment, providing the child with unique opportunities to acquire declarative knowledge. Furthermore, the processing mechanisms exercised during reading receive an unusual amount

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of practice. Certain microprocesses of reading which are linked to words or groups of words are repeatedly exercised. For example, from the time of at least the fifth grade, an avid reader is seeing literally millions of words a year (Anderson *et al.*, 1988). Thus, whatever cognitive processes are engaged over word or word-group units (phonological coding, semantic activation, parsing, induction of vocabulary items) are being exercised hundreds of times a day. It is surely to be expected that this amount of cognitive muscle-flexing will have some specific effects. Differential participation in such a process should result in large individual differences not only in reading ability but other cognitive skills as well.

Biemiller (1977–8) found large ability differences in exposure to print within the classroom as early as midway through the first year of school. Convergent results have been obtained by Allington (1984). In his sample of first-grade school children, the total number of words read during a week of school-reading group sessions ranged from a low of 16 for one of the children in the less skilled group to a high of 1,933 for one of the children in the skilled reading group. The average skilled reader read approximately three times as many words in the group reading sessions as the average less skilled reader. Nagy and Anderson have estimated that in the case of in-school reading

> the least motivated children in the middle grades might read 100,000 words a year while the average children at this level might read 1,000,000. The figure for the voracious middle grade reader might be 10,000,000 or even as high as 50,000,000. If these guesses are anywhere near the mark, there are staggering individual differences in the volume of language experience, and therefore, opportunity to learn new words. (Nagy and Anderson, 1984, p. 328)

There are, of course, also differences in the volume of reading outside the classroom which are linked to reading ability (Fielding *et al.*, 1986), and these probably become increasingly large as schooling progresses.

It is these individual differences in out-of-school reading volume and their resulting effects that we have attempted to model in our research programme. Although it has been shown that cognitive processes influence children's ability to read, very little attention has been focused on what might be considered a form of reciprocal causation – that is, on the possibility that differences in exposure to print affect the development of cognitive processes and acquisition of knowledge.

The effect of reading volume on cognitive processes and declarative knowledge bases, combined with the large skill differences in reading volume, could mean that a 'rich get richer' or cumulative advantage phenomenon is almost inextricably embedded within the developmental course of reading progress (see Stanovich, 1986). For example, we can see these 'the rich get richer' (and their converse 'the poor get poorer') effects in vocabulary development. The very children who are reading well and have good vocabularies will read more, learn more word meanings and hence read even better. Children with inadequate vocabularies – who read slowly and without enjoyment – read less, and as a result have slower development of vocabulary knowledge, which inhibits further growth in reading ability.

These educational sequences where early achievement in literacy spawns faster rates of subsequent achievement have been termed 'Matthew effects' by Stanovich (1986; see also Walberg and Tsai, 1983). The term 'Matthew effects' derives from the Gospel according to Matthew (XXV: 29): 'For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath' – and refers to the rich get richer and the poor get poorer effects embedded in the socio-developmental context of schooling. Reading comprehension provides an example of this effect – children who are already good comprehenders may tend to read more, thus spurring further increases in their reading comprehension abilities and increasing the achievement differences between them and their age cohorts who are not good comprehenders and not avid readers (Stanovich, 1986; Share and Silva, 1987; Juel, 1988; Share *et al.*, 1989; van den Bos, 1989; Chall *et al.*, 1990).

We shall attempt to examine these reciprocal effects in children's early reading development and evaluate their subsequent cognitive growth in the two studies reported in this chapter. Our first investigation delineates the relation between first-grade literacy environment and the development of children's orthographic and phonological skills. In our second study, we have followed a group of first-grade children and, ten years later, assessed their level of reading volume as well as their verbal intelligence, reading comprehension and general knowledge. In this longitudinal investigation, we have been able to observe the widening achievement disparities and the relative contribution of print exposure in explaining these differences.

An analytic logic for tracking the specific effects of print exposure

Over the past several years, our research group has attempted to develop and validate measures of individual differences in print exposure (e.g. Stanovich and West, 1989; Cunningham and Stanovich, 1990, 1991; West and Stanovich, 1991; Stanovich, 1992, 1993; Stanovich and Cunningham, 1992, 1993). We first examined the relation between print exposure and cognitive growth among adults (Stanovich and West, 1989) and later among children (e.g. Cunningham and Stanovich, 1990). In our methodology, we attempt to correlate differential engagement in reading with various cognitive outcomes that have been associated with the acquisition of literacy (Stanovich and West, 1989; Cunningham and Stanovich, 1990, 1991; West and Stanovich, 1991; Stanovich and Cunningham, 1992, 1993). However, such a logic, if not supplemented with additional methodological controls, is subject to the same problem that has plagued historical investigations of literacy's effects – the problem of spurious correlation. That is, degree of print exposure is correlated with various reading skills such as word decoding and with cognitive abilities generally. Simply and obviously, individuals with superior reading skills read more. This correlation is problematic

because it raises the possibility that an association between amount of print exposure and any criterion ability, skill or knowledge base might arise not because of the unique effects of print exposure, but because of individual differences in general ability or in specific reading subskills such as decoding.

This point can be illustrated using vocabulary as an example. The counter-argument to the claim that print exposure is a major mechanism determining vocabulary growth (Nagy and Anderson, 1984; Stanovich, 1986; Hayes, 1988) is that superior decoding ability leads to more print exposure, and that decoding abilities are themselves related to vocabulary development because better decoding ensures an accurate verbal context for inducing the meanings of unknown words. Thus, according to this argument, vocabulary and print exposure are spuriously related via their connection with decoding ability: good decoders read a lot and have the best context available for inferring new words. Decoding ability could also in part reflect the efficiency of the phonological short-term memory which Gathercole and Baddeley (1989) have argued is critical to early oral vocabulary acquisition. Finally, vocabulary and print exposure could be spuriously linked through general cognitive abilities which are associated with both print exposure and the ability to induce meaning from context (Sternberg, 1985).

We have utilized a regression logic to deal with this problem. In the analyses to be discussed, we shall first control statistically for the effects of general ability before examining the relationship between print exposure and criterion variables. This procedure of reducing possible spurious relationships by first partialling out relevant subskills and abilities and then looking for residual effects of print exposure has been used in our earlier investigations. For example, in previous work we have demonstrated that independent of decoding ability, variation in print exposure among adults predicts spelling ability and orthographic knowledge (Stanovich and West, 1989). Similarly, in a previous study of children's performance (Cunningham and Stanovich, 1990) we found that after partialling IQ, memory ability and phonological processing abilities, print exposure accounted for additional variance in orthographic knowledge and word recognition. The logic of our analytic strategy is quite conservative because we partial out variance in abilities that are likely to be developed by print exposure itself (Stanovich, 1986, 1993). Yet even after print exposure is robbed of some of its rightful variance, it remains a unique predictor (Stanovich and West, 1989).

Assessing print exposure

There are numerous difficulties involved in assessing individual differences in exposure to print. Time diary methods, in which daily activity records are filled out by subjects (see Greaney, 1980; Greaney and Hegarty, 1987; Anderson *et al.*, 1988; Taylor *et al.*, 1990), result in estimates of the absolute amount of time spent on literacy activities. Other techniques are available if one wants only an index of relative differences in exposure to print. For example, a variety of questionnaire and interview techniques has been used to assess relative differences in print exposure (e.g. Estes, 1971; Sharon, 1973–4; Lewis and Teale, 1980; Guthrie, 1981; Guthrie and Greaney, 1991; Guthrie and Seifert, 1983), but many of these are encumbered with social desirability confounds: responses are distorted due to the tendency to report socially desirable behaviours (Paulhus, 1984; Furnham, 1986) – in this case, the tendency to report more reading than actually takes place (Ennis, 1965; Sharon, 1973–4). This problem is particularly acute within the context of the present study where primary and secondary school children are being asked questions about a socially valued activity such as reading.

In this chapter, we report further data on three recognition measures of print exposure – the Author Recognition Test, the Magazine Recognition Test and the Title Recognition Test – measures that have proved to be robust predictors in earlier studies (Stanovich and West, 1989; Cunningham and Stanovich, 1990, 1991; West and Stanovich, 1991; Allen *et al.*, 1992; Cipielewski and Stanovich, 1992; Stanovich and Cunningham, 1992, 1993; West *et al.*, 1993).

The first measures we developed were designed for use with adult subjects (Stanovich and West, 1989). The Author Recognition Test (ART) and the Magazine Recognition Test (MRT) both exploited a signal detection logic whereby actual target items (real authors and real magazines) were embedded among foils (names that were not authors or magazine titles, respectively). Subjects simply scan the list and check the names they know to be authors on the ART, and the titles they know to be magazines on the MRT. The measures thus have a signal detection logic. The number of correct items checked can be corrected for differential response biases which are revealed by the checking of foils. Although checklist procedures have been used before to assess print exposure (Chomsky, 1972), our procedure is unique in using foils to control for differential response criteria (see Stanovich and Cunningham, 1992, for examples of the stimuli).

In constructing the ART list, authors were selected who were most likely to be encountered outside the classroom, so that the ART would be a proxy measure of out-of-school print exposure rather than of curriculum exposure. Thus, an attempt was made to avoid authors who are regularly studied in the school curriculum. For example, none of the authors that we have employed appeared in Ravitch and Finn's (1987) survey of secondary school curriculum literature. In short, the ART was intentionally biased towards out-of-school reading, because it was intended as an indirect measure of amount of free reading. The ART is dominated by 'popular' authors. That is, it is not composed of 'highbrow' writers who would be known by only the most highly educated or academically inclined readers. Instead, many of the book authors regularly appear on best-seller lists and most have sold hundreds of thousands, if not millions, of copies. Although no statistical sampling of authors was carried out, an attempt was made to mix writers from a wide variety of genres.

Similarly, the sampling of titles on the MRT was deliberately biased towards popular publications. 'Highbrow' academic and low-circulation small press

publications which would be known by only the most highly educated or academically inclined readers were avoided. The publications on the MRT almost all have circulations in the hundreds of thousands – in many cases, millions. The foil items on the MRT do not appear in the 60,000 listings in *The Standard Periodical Directory* (Manning, 1988) and the foil names on the ART were drawn from lists of editorial board members of psychological and educational journals.

This checklist method has several advantages. First, it is immune to the social desirability effects that may contaminate responses to subjective self-estimates of socially valued activities such as reading. Guessing is not an advantageous strategy because it is easily detected and corrected for by an examination of the number of foils checked. Further, the cognitive demands of the task are quite low. The task does not necessitate frequency judgements as do most questionnaire measures of print exposure, nor does it require retrospective time judgements as does the use of daily activity diaries. Finally, the measures can be administered in a matter of a few minutes.

These checklist tasks are of course proxy indicators of someone's print exposure rather than measures of absolute amounts of reading in terms of minutes or estimated words (Anderson *et al.*, 1988). The fact that the measures are very indirect proxy indicators is problematic in some contexts, but it is also sometimes a strength. Clearly, hearing about a magazine or author on television without having been exposed to the actual written work is problematic. The occurrence of this type of situation obviously reduces the validity of the tasks. However, a post-experimental comment sometimes made by adult subjects in our studies is worth noting: some subjects said they knew a certain name was that of an author, but had never read anything that the author had written. When questioned about how they knew that the name was a writer, the subjects often replied that they had seen one of the author's books in a bookshop, had seen an author's book in the 'new fiction' section of the library, had read a review of the author's work in *Newsweek*, had seen an advertisement in the newspaper, etc. In short, knowledge of that author's name was a proxy for reading activities, despite the fact that the particular author had not actually been read. Thus, although some ways of gaining familiarity with author names would reduce validity (TV, radio), most behaviours leading to familiarity with the author names are probably reflections of immersion in a literate environment.

The Title Recognition Test (TRT) is a measure that has the same signal detection logic as the adult ART and MRT, but involves children's book titles rather than authors or magazines as items. This children's measure shares the same advantages of immunity from socially desirable responding, objective assessment of response bias, low cognitive load and lack of necessity for retrospective time judgements. The TRT consists of an intermixed list of actual children's book titles and foils for book names. The titles utilized were selected from a sample of book titles generated in pilot investigations by groups of children aged 6–8 years, by examining various lists of children's titles, and by consulting teachers and reading education professionals knowledgeable about current trends in children's literature. In selecting the items to appear on the TRTs used in our investigations, we attempted to choose titles that were not prominent parts of classroom reading activities in the schools in which our studies were to be conducted. Because we wanted the TRT to reflect out-of-school rather than school-directed reading, we attempted to avoid books that were used in the school curriculum. Thus, if the test is used for this purpose, versions of it will necessarily differ somewhat in item content from classroom to classroom and from school to school.

The score on all of these checklists – both child and adult versions – was the proportion of correct items checked minus the proportion of foils checked. This is the discrimination index from the two-high threshold model of recognition performance (Snodgrass and Corwin, 1988). Other corrections for guessing and differential criterion effects (*ibid.*) produce virtually identical correlational results.

Early literacy environment and the development of orthographic and phonological skills

With the exception of the seminal work of Maclean *et al.* (1987) on knowledge of nursery rhymes, there has been very little work on the experiential correlates of early phonological and orthographic processing skill. We addressed this issue in the present investigation by examining whether children's phonological and orthographic processing skill is differentially related to our index of children's home literacy environment – an index that is probably an indirect indicator of individual differences in exposure to print.

In a study of 26 first-grade (6–7 years) readers, we relied primarily on three tasks to partial out phonological processing variance. The first was a deletion task which required the children to delete the initial consonant from a monosyllabic word and pronounce the embedded word. In the second deletion task, the children were required to delete the initial phoneme from a series of ten beginning consonant blends and pronounce the remaining embedded word or word-like segment. The second part of this task required the children to delete the final phoneme from a series of ten final consonant blend words and provide the remaining sounds. Our third measure was a phoneme transposition task. Essentially, the children were required to switch the beginning and ending phoneme of a monosyllabic word to create a new word (e.g. top – pot).

In addition to the spelling subtest of the Stanford Achievement Test (Primary 1, Form E), two other tasks served as measures of orthographic processing skill. The first task was taken in part from Mann *et al.*'s spelling study (1987). Target words contained at least one of the following attributes: a letter name within the word, a short vowel, a nasal, a liquid or a consonant represented with a digraph. The words were chosen to 'increase the likelihood that subjects would invent preconventional spellings that could easily be distinguished from conventional spellings' (Mann *et al.*, 1987, p. 126). To spell these items conventionally, an orthographic representation must be consulted, so that accuracy on the items becomes, at least in part, a measure of the quality of the early developing orthographic lexicon.

The third orthographic processing measure was a letter-string choice task. Stimuli were kindly provided by Rebecca Treiman. The children were presented with sixteen pairs of 3–7 letter-strings on a sheet of paper and instructed to circle the one word that looked most like it could be a real word. The children are told that neither string is an actual word, but that one letter-string is more *like* a word. One member of each pair contained an orthographic sequence that either never occurs in English or that occurs with extremely low frequency. The subject's score is the number of times that the nonword without the illegitimate or low-frequency letter-string was chosen. Although this task undoubtedly implicates phonological coding to some extent, the coding of frequent and infrequent orthographic sequences in memory should be a substantial contributor to performance. Stimuli were: beff–ffeb, ddaled–dalled, yikk–yinn, vadding–vayying, nuck–ckun, ckader–dacker, vadd–vaad, muun–munt, ist–iit, moyi–moil, aut–awt, bey–bei, dau–daw, gri–gry, chim–chym and yb–ib.

Finally, a standardized reading achievement test, the Stanford Achievement Test (Primary 1, Form E), was employed to assess children's word reading and spelling performance.

As described earlier, the Title Recognition Test (TRT) was designed as an analog of recognition measures that had previously been used to assess amount of exposure to print in adults and primary school children. In the present study employing much younger children, the measure could be viewed as a proxy for the general literacy environment in the home or, alternatively, as a measure of the child's own print exposure. The TRT was group-administered within the classroom. The title of each book was read to children and they were instructed to underline only the names of books they knew were actual books. The children were told that guessing could easily be detected because some of the titles were not the names of actual books.

Can orthographic processing ability account for unique variance in word recognition?

By utilizing the logic of hierarchical multiple regression we addressed the question of whether there is variance in word recognition that can be reliably linked to orthographic processing skill once variance due to phonological processing has been partialled out. Table 5.1 presents the results of two such analyses. The three phonological processing tasks were entered first and collectively achieved a multiple R with Stanford Word Reading of 0.504. However, when the letter-string choice task was entered fourth, it accounted for a substantial proportion of additional variance (30.1 per cent). Similarly, when the score on the experimental spelling test was entered as the fourth variable in the equation, it accounted for 29.1 per cent of the variance in Word Reading scores.

Table 5.1 Intercorrelations among variables in the study

Variable	1	2	3	4	5	6	7	8
1. Title Recognition Test Derived								
2. SAT Word Reading	0.64							
3. SAT Spelling	0.69	0.71						
4. Phoneme Deletion1	0.01	0.40	0.22					
5. Phoneme Deletion2	0.16	0.39	0.10	0.30				
6. Phoneme Transposition	− 0.04	0.20	− 0.11	0.50	0.50			
7. Letter-string Choice	0.39	0.63	0.57	0.02	0.42	0.01		
8. Experimental Spelling	0.50	0.70	0.43	0.43	0.50	0.47	0.40	

Note:
Correlations greater than 0.33 are significant at the 0.05 level (two-tailed).

Thus, there does seem to be variation in orthographic processing skill, which is linked to word recognition ability and is independent of phonological processes. The analyses reported here are at least a tentative indication that phonological and orthographic processing skills are separable components of variance in word recognition during the very earliest stages of reading acquisition. The development of print-specific knowledge is not entirely parasitic on phonological processing skill among beginning readers.

Can variance in orthographic processing ability be linked to print exposure differences that are independent of phonological processing skill?

The latter conclusion shifts attention to the question of what factors determine variation in orthographic processing abilities and, in particular, whether print exposure is related to orthographic processing skill. In exploring this relationship it is important to partial out phonological processing ability because even if differences in orthographic processing abilities had as their proximal cause differences in exposure to print, reading practice may simply be determined by how skilled the child is at phonological processing. If this is the case, then print exposure would not serve as a unique source of orthographic variance once phonological processing skill was partialled out.

The hierarchical regression analyses presented in Table 5.2 address this question. The criterion variable in the first analysis is the score on the letter-string choice task. Entered first are the three phonological processing tasks which attain a multiple R of 0.480. Entered last is the score on the TRT and it accounts for an additional 8.5 per cent of the variance. However, probably due to the modest size of the sample, this unique proportion of variance explained did not reach statistical significance ($F(1, 21) = 2.63$). The second hierarchical regression was conducted with the experimental spelling test performance as the criterion variable. The three phonological tasks attained a multiple R of 0.595

Table 5.2 Unique print exposure variance after phonological and orthographic processing variance is partialled out

Dependent variable	Predictors	Multiple R	R^2 change
Letter-string Choice	Phoneme Deletion1	0.020	0.020
	Phoneme Deletion2	0.435	0.169*
	Phoneme Transposition	0.480	0.042
	Title Recognition Test	0.563	0.085
Experimental Spelling	Phoneme Deletion1	0.432	0.432*
	Phoneme Deletion2	0.576	0.245*
	Phoneme Transposition	0.595	0.042
	Title Recognition Test	0.753	0.212*
Stanford Spelling	Phoneme Deletion1	0.224	0.224*
	Phoneme Deletion2	0.227	0.001
	Phoneme Transposition	0.365	0.083
	Title Recognition Test	0.753	0.432*
Stanford Word Reading	Phoneme Deletion1	0.401	0.401*
	Phoneme Deletion2	0.490	0.079
	Phoneme Transposition	0.504	0.010
	Title Recognition Test	0.777	0.349*

Note:
* $p < 0.01$.

when entered as the first three steps. When entered as the last step, the TRT accounted for a statistically significant 21.2 per cent of the variance.

The third hierarchical regression was conducted with Stanford Spelling subtest scores as the criterion variable. This task was assumed to contain substantial orthographic processing variance because it is a spelling recognition test and because it displayed substantial correlations with performance on the letter-string choice task and the experimental spelling test (see Table 5.1). The three phonological tasks had a multiple R of 0.365 with performance on the Spelling subtest. When entered as the fourth step, the TRT accounted for a substantial 43.2 per cent of additional variance. Thus, in two of the three analyses reported here, exposure to print (as measured by the TRT) accounted for significant variance in orthographic processing variance once individual differences in phonological processes had been statistically controlled. The orthographic processing knowledge or processing skill that is separable from phonological processes appears to be linked to individual differences in the children's experiential history of literacy activities.

The final hierarchical regression shown in Table 5.2 simply illustrates that performance on the TRT also accounts for significant variance in Stanford Word Reading scores after phonological abilities have been partialled out.

In summary, this study demonstrates that it is possible to separate variance in orthographic processing skill from variance in phonological processing ability very early in the reading acquisition process. The findings converge with investigations of older children and adults (e.g. Treiman, 1984; Bryant and Impey, 1986;

Freebody and Byrne, 1988; Stanovich and West, 1989; Cunningham and Stanovich, 1990).

There is a substantial body of evidence on the importance of phonological processing in early reading, but less is known about how orthographic processing skill and/or the buildup of an orthographic lexicon interacts with the early stages of reading acquisition. This study has linked at least part of this variance in orthographic structures and/or processes to variation in children's literacy environments which can be measured with a very simple indicator. The study has demonstrated, in the orthographic domain, how reading might itself develop skills and knowledge bases which then serve to enable more efficient subsequent reading. We are just beginning to understand the mechanisms by which print exposure differences act to create rich get richer and poor get poorer effects in educational achievement (Stanovich, 1986, 1993). Our second study sheds further light on the relation between early literacy environment and the development of children's cognitive skills and more general knowledge bases.

A longitudinal investigation of print exposure and the development of cognitive skills

In a study of 56 first-grade readers (6–7 years) we administered a battery of tasks, which included measures of intelligence (Otis-Lennon School Ability Test and Raven Progressive Coloured Matrices, 1962), vocabulary (Peabody Picture Vocabulary Test, PPVT) and reading achievement (Metropolitan Reading Achievement Test, 1978). The cognitive performance of the children was tracked during the subsequent ten-year period. In the latter part of this study, we assessed a variety of declarative knowledge bases and verbal skills as well as the students' level of print exposure. Twenty-seven eleventh-grade (16–17 years) students remained from our earlier sample. The variables we report in this chapter are two measures of vocabulary (the Peabody Picture Vocabulary Test and the Nelson–Denny Reading Test: Vocabulary, Form F), two measures of general knowledge (National Assessment of Educational Progress Test of History and Literature, Ravitch and Finn, 1987, and Cultural Literacy Test, Riverside Publishing, 1989), a measure of reading comprehension (Nelson–Denny Reading Test: Comprehension, Form F) and secondary school versions of the ART and MRT.

Print exposure as a predictor of ten years of cognitive growth

A primary purpose of this study was to track the relation between children's literacy environment and their subsequent cognitive skill level. A composite z score of the ART and MRT was created for the following analyses (ARTMRTZ).

Table 5.3 Print exposure as a predictor of increase in reading ability (first to third grade) after differences in general ability are partialled out

Criterion variable = Third-grade Metropolitan Achievement Test, Elementary		
Step	Multiple R	R^2 change
1. First-grade Raven	0.119	0.013
2. First-grade PPVT	0.245	0.047
3. First-grade WRAT	0.595	0.294*
4. ARTMRTZ	0.734	0.185*
1. First-grade Raven	0.119	0.014
2. First-grade PPVT	0.308	0.081
3. First-grade MAT	0.789	0.528*
4. ARTMRTZ	0.833	0.071**

Notes:
* $p < 0.01$.
** $p < 0.05$.

In some of these analyses, we interpreted the print exposure measures as cumulative indicators of variance in reading volume which had taken place many years earlier. Although we did not measure the literacy environment directly in the early years of our study, presumably the variance in the indicators reflects not just variance at the time of testing but also variance occurring during early years as well. Thus, we view the measures as in some sense retrospective indicators, tapping the cumulative experiences and habits of the children during the entire time-period.

In our first set of longitudinal analyses, we addressed the question of whether our retrospective index of exposure to print (ARTMRTZ) could predict growth in reading ability from the first to the third grade. To control for differences in general ability, first-grade performance on the Raven Progressive Matrices and the Peabody Picture Vocabulary Test were entered first into the regression equation predicting third-grade performance on the Metropolitan Achievement Test, Elementary. Collectively, the Raven and PPVT accounted for just 6.0 per cent of the variance in third-grade reading ability as measured by the Metropolitan Achievement Test, Elementary. When first-grade performance on the Reading subtest of the Wide Range Achievement Test was entered as the third step, it accounted for a substantial 29.4 per cent additional variance (F (1,22) = 9.95). However, when our measure of print exposure was entered as the fourth step, it still accounted for a sizeable 18.5 per cent additional variance in third-grade reading ability (F (1,22) = 6.95). When first-grade performance on the Metropolitan Achievement Test, Primary was substituted for the WRAT in a parallel analysis, the MAT accounted for 53.1 per cent additional variance and print exposure accounted for a smaller but still significant 7.1 per cent additional variance (F (1,22) = 4.43).

Table 5.4 Print exposure as a predictor of increase in reading ability (first to eighth grade) after differences in general ability are partialled out

Step	Multiple R	R^2 change
Criterion variable = Eighth-grade Metropolitan Achievement Test, Intermediate		
1. First-grade Raven	0.009	−0.048
2. First-grade PPVT	0.158	0.025
3. First-grade WRAT	0.687	0.276*
4. ARTMRTZ	0.745	0.183*
1. First-grade Raven	0.009	0.048
2. First-grade PPVT	0.158	0.025
3. First-grade MAT	0.687	0.447*
4. ARTMRTZ	0.745	0.083*

Note:
* $p < 0.01$.

A similar pattern was observed across a broader age range (see Table 5.4). In a second set of hierarchical regression analyses, our criterion variable was performance on the eighth-grade Metropolitan Achievement Test, Intermediate and the predictor variables were first-grade Raven, PPVT, MAT, WRAT and print exposure. Parallel to the previous analysis, this analysis addresses the question of whether print exposure can predict first- to eighth-grade growth in reading ability after general ability differences in the first grade are partialled. Collectively, the Raven and PPVT attained a non-significant multiple R of 0.158 (F (1,22) = 0.507). When the WRAT was entered at the third step, it accounted for 27.6 per cent additional variance. Entered last was the print exposure composite (ARTMRTZ), which accounted for a statistically significant 18.3 per cent of the variance (F (1,22) = 6.39). In a similar sequence, the MAT was entered after the Raven and PPVT and contributed 44.7 per cent additional variance. Entered next, print exposure accounted for 8.3 per cent additional variance (F (1,22) = 4.32). The results of these analyses demonstrate that print exposure accounted for significant variance in later reading ability once individual differences in general ability and first-grade reading ability were statistically controlled.

Table 5.5 displays a third hierarchical regression employing eleventh-grade reading comprehension ability (Nelson–Denny Reading Comprehension) as the criterion variable. Fifth-grade MAT performance was entered first and attained a multiple R of 0.625. Scores on the Raven matrices administered in the eleventh grade were entered next and accounted for a non-significant 2.2 per cent of the variance (F (1,23) = 0.80). When entered as the last step, the ARTMRTZ composite accounted for a statistically significant 5.8 per cent of the variance (F (1,23) = 5.92) – thus demonstrating that an indicator of exposure to print can predict individual differences in growth in reading comprehension from the fifth to the eleventh grade.

Table 5.5 Print exposure as a predictor of increase in reading ability (fifth to eleventh grade)

Step	Multiple R	R^2 change
Criterion variable = Nelson–Denny Reading Test: Comprehension		
1. Fifth-grade MAT	0.625	0.390*
2. Eleventh-grade Raven	0.642	0.022
3. ARTMRTZ	0.696	0.058**

Notes:
* $p < 0.01$.
** $p < 0.05$.

These are just a sampling of numerous analyzers, which demonstrate basically the same thing: that growth in reading comprehension ability between any two grades between the first and the eleventh grade is predicted by an index of print exposure administered in the eleventh year.

First-grade cognitive skills as predictors of subsequent print exposure

Our next set of analyses explored the relation between children's early cognitive skill levels and subsequent exposure to print. These analyses explore – correlationally, of course – the relative contributions of general abilities and early reading comprehension skill in explaining individual differences in children's literacy environments. Any indication that early comprehension ability plays a significant role in determining individual differences in subsequent print exposure would be consistent with the existence of Matthew effects in reading development.

Table 5.6 displays a hierarchical analysis in which the performance on the first-grade administration of the Raven matrices was entered as step 1 and attained a multiple R of 0.328 with the criterion variable (ARTMRTZ score). Performance on the Peabody Picture Vocabulary Test was entered second and predicted 23.4 per cent additional variance in subsequent print exposure. Performance on the first-grade administration of the WRAT predicted a sizeable 38.5 per cent of the variance (F (1,23) = 8.55). Performance on the first-grade Metropolitan was also entered in this same sequence and contributed a smaller but still significant 21.9 per cent additional variance (F (1,23) = 9.76). Although correlational, these results lend further support to the hypothesis that early reading ability plays a significant role in shaping one's later literacy environments. The rich appear to get richer, not only in terms of absolute levels of reading ability, but in their levels of print exposure as well.

Table 5.6 Cognitive skills (first grade) as a predictor of print exposure

Criterion variable = ARTMRTZ Step	Multiple R	R^2 change
1. Raven	0.328	0.107
2. PPVT	0.584	0.234*
3. WRAT	0.726	0.385*
1. Raven	0.328	0.107
2. PPVT	0.584	0.234*
3. MAT	0.748	0.219*

Note:
* $p < 0.01$.

Print exposure as a predictor of knowledge and vocabulary

One mechanism by which print exposure might lead to cognitive change is as a builder of an individual's knowledge base. Very little attention has focused on this form of reciprocal causation – that is, on the possibility that differences in exposure to print affect the development of declarative knowledge bases (see, however, Stanovich and Cunningham, 1993). Thus, our next set of analyses were structured to address the issue of whether measures of print exposure can account for variance in declarative knowledge after variance in relevant prior abilities has been partialled out.

In our first set of analyses, the criterion variable was eleventh-grade vocabulary scores on the Nelson–Denny Reading Test: Vocabulary. The first hierarchical regression displayed in Table 5.7 partialled fifth-grade reading ability (Metropolitan Reading Achievement Test, Elementary) and performance on the eleventh-grade Raven matrices before entering the index of print exposure. Fifth-grade MAT attained a multiple R of 0.431 and eleventh-grade Raven contributed 23.3 per cent additional variance. Print exposure accounted for a sizeable 33 per cent additional variance in vocabulary knowledge (F (1,23) = 17.37).

Because it could be argued that partialling reading comprehension ability from these analyses is unduly conservative (see Stanovich, 1993; Stanovich and Cunningham, 1993), we conducted a further analysis, which partialled two tests of general ability, one administered in the fifth grade and the other in the eleventh grade. Fifth-grade performance on the Otis–Lennon School Ability Test was partialled, followed by eleventh-grade Raven performance and then the print exposure composite. The combined multiple R of the two ability measures was 0.397. Print exposure was entered last and accounted for 51 per cent additional variance. Print exposure is thus the dominant predictor of vocabulary knowledge in these analyses.

In a parallel set of analyses, we examined the relative contribution of print exposure towards general knowledge as measured by National Assessment of

Table 5.7 Variance in declarative knowledge as predicted by print exposure (eleventh grade)

Criterion variable = Nelson–Denny Reading Test: Vocabulary – Eleventh-grade Step	Multiple R	R^2 change
1. Fifth-grade MAT	0.431	0.186*
2. Eleventh-grade Raven	0.647	0.233*
3. ARTMRTZ	0.866	0.331*
1. Fifth-grade Otis–Lennon	0.172	0.030
2. Eleventh-grade Raven	0.397	0.128
3. ARTMRTZ	0.817	0.509*
Criterion variable = General Knowledge – Eleventh Grade		
Step		
1. Fifth-grade MAT	0.503	0.253*
2. Eleventh-grade Raven	0.531	0.029
3. ARTMRTZ – Eleventh-grade	0.674	0.172*
1. Fifth-grade Otis–Lennon	0.244	0.060
2. Eleventh-grade Raven	0.482	0.172*
3. ARTMRTZ	0.676	0.225*

Note:
* $p < 0.01$.

Educational Progress Test of History and Literature (Ravitch and Finn, 1987) and Cultural Literacy Test (Riverside Publishing, 1989). As displayed in the bottom half of Table 5.7, print exposure explained a significant 17.2 per cent additional variance in general knowledge after fifth-grade MAT and eleventh-grade Raven were partialled. When just the nonverbal ability measures of fifth-grade Otis–Lennon and eleventh-grade Raven were entered, print exposure subsequently explained 22.5 per cent additional variance.

The results displayed in Table 5.8 examine print exposure as a concurrent predictor of declarative knowledge. In these analyses, we entered eleventh-grade Raven and Nelson–Denny reading comprehension prior to our print exposure measure. Each variable accounted for significant additional variance when entered in this order, and as a set resulted in a multiple correlation of 0.632. This particular conservative regression analysis, by entering concurrent reading comprehension ability, attempts to 'stack the deck', so to speak, against our index of literacy experience. We do not, of course, mean to imply by structuring the analyses in this way that print exposure is not a determinant of reading comprehension ability. Our intention is merely to bias the analyses against our print exposure measure, thereby controlling for any spurious relation with ability. None the less, we found that print exposure accounted for 35 per cent additional variance in vocabulary knowledge. Print exposure accounted for a significant, but much smaller, amount of the variance in general knowledge (7 per cent). Despite the conservative structuring of the analyses, print exposure appears to be a

Table 5.8 Print exposure as a concurrent predictor of knowledge and vocabulary

Criterion variable = Nelson–Denny Reading Test: Vocabulary – Eleventh-grade Step	Multiple R	R^2 change
1. Eleventh-grade Raven	0.552	0.305*
2. Eleventh-grade Nelson–Denny Comprehension	0.632	0.095*
3. ARTMRTZ	0.864	0.346*
Criterion variable = General Knowledge – Eleventh Grade		
Step		
1. Eleventh-grade Raven	0.402	0.161*
2. Eleventh-grade Nelson–Denny Comprehension	0.744	0.393*
3. ARTMRTZ	0.787	0.065*

Note:
* $p < 0.01$.

powerfully unique predictor of the declarative knowledge bases of secondary school pupils.

Conclusions

The results of these analyses suggest that print exposure, although clearly a consequence of developed reading ability, is probably a significant contributor to the development of other aspects of verbal intelligence. Such rich-get-richer and their converse (poor-get-poorer) effects are becoming of increasing concern to educational practitioners (Chall, 1989; Adams, 1990) and are playing an increasingly prominent role in theories of individual differences (Nagy and Anderson, 1984; Stanovich, 1986, 1988, 1993; Anderson *et al.*, 1988; Hayes, 1988; Hayes and Ahrens, 1988; Juel, 1988; Siegel, 1989; van den Bos, 1989; Chall *et al.*, 1990). Several authors have emphasized that both in and out of school, readers of higher ability are progressively exposed to more print than their less skilled peers, thus leading to an increasing divergence in the performance of skilled and less skilled readers (Biemiller, 1977–8; Allington, 1980, 1983, 1984; Nagy and Anderson, 1984; Nagy, Herman and Anderson, 1985; Stanovich, 1986; Anderson *et al.*, 1988; Juel, 1988).

Our longitudinal analyses have provided us with a window on the past literacy experiences of our first-grade sample and provided some clues as to the cause of their subsequent divergences in reading ability and vocabulary. It is likely that our check-list measures of print exposure tap into individual differences in exposure to print outside the classroom (Allen *et al.*, 1992; Stanovich, 1993; West *et al.*, 1993) and our results indicate that such print exposure differences are uniquely predictive of certain cognitive outcomes. These results, along with earlier work (Anderson *et al.*, 1988; Hayes, 1988; Cunningham and Stanovich, 1990, 1991; Guthrie, Schafer and Hutchinson, 1991; West and Stanovich, 1991; Stanovich and Cunningham, 1992, 1993), strengthen the case for expanding our models of reading development and general theories of cognitive development to include a more prominent role for exposure to print. We propose a more complex causal model than is common in individual differences research – one that views individual differences in basic cognitive processes and knowledge bases as at least in part resulting from the experience of reading itself (see Stanovich, 1986, 1993; Stanovich and Cunningham, 1993). Given that cognitive and developmental psychologists continue to emphasize the importance of domain knowledge in determining processing efficiency (Keil, 1984; Chi, Hutchinson and Robin, 1989; Ceci, 1990), it may pay to focus further research attention on reading as a mechanism that builds knowledge bases and that exercises verbal talents.

Our studies, of course, do not say anything about how the differential exposure to print comes about. We have only demonstrated that variance in general ability is not completely coextensive with variance in amount of reading. Certainly, environmental differences such as cultural opportunities, parental modelling and quality of schooling may be a contributing factor. Active as well as passive organism/environment correlations (see Scarr and McCartney, 1983) may be an important factor in determining individual differences in print exposure. Children who exhibit high interest often have greater access to print, are read to more often and watch less television (e.g. Morrow, 1983). Additionally, personality dispositions towards literacy activities may also play a role, and the environmental and genetic determinants (see Plomin *et al.*, 1990) of such behavioural propensities are completely unknown.

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6

Basic mechanisms in learning to read

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Introduction

This chapter deals with the mechanisms of visual word identification. The focus will be on reading difficulties experienced by developing readers. Their problems will be contrasted with normally reading peers and skilled performance observed in adults. It is impossible to present a complete overview of the research literature here. Rather, we shall focus on just one aspect in this chapter. Our purpose is to present a set of our own experiments comparing normal and poor readers in their use of word identification mechanisms. This comparison will be made at various processing levels involved in word identification. We do *not* deal with the development of word identification in early reading.

Our focus will be on word identification skills emerging after the child has mastered the basics of reading. This period is completed when the child has learned the sound–spelling correspondences and has progressed from decoding words on an individual letter basis to fluent reading by automatic word recognition. This is normally achieved at the age of about 8 or 9 years.

When the child identifies a string of letters as a word, he or she performs an amazingly complex skill. Word identification is concerned not only with discriminating single letters, it also involves extracting information beyond the single letter level. In this chapter we shall discuss mechanisms involved at various processing levels in a bottom-up fashion.

We start our excursion with the mechanisms working at the *letter feature level*, followed by a discussion of processes affecting the *individual letter level*. Then, the *letter cluster level*, the intermediate stage between the single letter and the *whole word level*, will be dealt with. Next we present research focusing on identification