

## Assessing Print Exposure and Orthographic Processing Skill in Children: A Quick Measure of Reading Experience

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In a study of third- and fourth-grade children it was established that orthographic processing ability can account for variance in word recognition skill after the variance due to phonological processing has been partialled out. This independent orthographic variance was related to performance on a new measure of individual differences in exposure to print, the Title Recognition Test (TRT), that has a very brief administration time. Additionally, some of the orthographic processing variance linked to word recognition ability was not shared with either phonological processing measures or with print exposure. The results of the study were supportive of the idea that there are individual differences in word recognition ability caused by variation in orthographic processing abilities that are in part determined by print exposure differences.

It is hardly surprising that considerable attention has recently been given to the role of phonological processes in reading acquisition. An enormous amount of research has indicated that there are critical linkages between the development of phonological abilities and the acquisition of word recognition skills (Juel, 1988; Kamhi & Catts, 1989; Liberman & Shankweiler, 1985; Perfetti, 1985; Stanovich, 1986, 1988a, 1988b; Treiman & Baron, 1983; Vellutino & Scanlon, 1987). Nevertheless, despite the importance of phonological variables in explaining variance in the acquisition of word recognition skill, it is possible that another class of factors could explain additional variance. Although the correlations between phonological processing skill and word recognition ability are quite high, they still probably leave some reliable word recognition variance unaccounted for (Stanovich, Cunningham, & Cramer, 1984; Wagner, 1988; Wagner & Torgesen, 1987; Yopp, 1988). In addition, some investigators have argued that the development of a minimal level of phonological sensitivity is a necessary but not sufficient condition for the development of efficient word recognition processes (Juel, Griffith, & Gough, 1986; Tunmer & Nesdale, 1985).

Recently, theoretical attention has centered on orthographic processing abilities as a potential second source of variance in word recognition ability (see Stanovich & West, 1989). However, isolating individual differences on this dimension is problematic because there is little doubt that the

development of orthographic processing skill must be somewhat dependent on phonological processing abilities (Barron, 1986; Ehri, 1984, 1987; Jorm & Share, 1983). The critical question for research is whether the development of the orthographic lexicon is *entirely* parasitic on the operation of phonological processes. In a study using adult subjects, Stanovich and West (1989) obtained data that answered this question in the negative. They found that even after the considerable variance associated with phonological processing had been partialled out, orthographic processing skills explained significant additional variance in reading and spelling ability.

In further analyses, Stanovich and West (1989) found that differences in amount of exposure to print were linked to orthographic processing variance after phonological abilities had been partialled out. This was no trivial finding because it is quite possible that print exposure differences could have been entirely parasitic on phonological processing abilities. The problem is that 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 reader is at phonological coding. This conjecture yields the prediction that print exposure differences should not account for variance in orthographic processing efficiency, once the influence of phonological skill has been removed. It is just this prediction that was falsified by the results reported by Stanovich and West (1989).

In the study reported here, we attempted to extend these findings to the performance of children because the conclusions derived from the Stanovich and West (1989) study were based entirely on studies of adult readers. First, we addressed the issue of whether orthographic processing ability accounts for variance in word recognition skill once the variance associated with phonological processing has been partialled out. To address this question we administered, in addition to a standardized word recognition test, converging measures of phonological processing skill and converging measures of orthographic processing skill to third- and fourth-grade children. These same measures were used to address the second question: whether print exposure differences are linked to the

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variability in orthographic processing that is not explained by differences in phonological processing skill. Measures of nonverbal problem-solving skill and general memory skill were also administered so that nonspecific cognitive abilities could be partialled out from the analyses.

To test the second prediction, we developed a children's measure of print exposure that was analogous to the recognition tasks that Stanovich and West (1989) used as indicators of print exposure in adults: the Author Recognition Test (ART) and the Magazine Recognition Test (MRT). Both of these measures 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). The subject simply goes down the list and checks those names known to be authors on the ART and those names known to be magazines on the MRT. The task is immune to the social desirability effects that so contaminate responses to self-estimates of socially valued activities such as reading (Ennis, 1965; Paulhus, 1984; Sharon, 1973-1974). Guessing is not an advantageous strategy because it is easily detected and corrected for by an examination of the number of foils checked. Furthermore the cognitive demands of the task are low.

In the present investigation, we developed an analogous measure for children, the Title Recognition Test (TRT). The measure has the same signal detection logic as the adult ART, but uses children's book titles rather than authors as items. The children's measure has the same advantages of low cognitive load, freedom from subjective judgments, and objective assessment of response bias.

## Method

### Subjects

The subjects were 51 third-grade children (23 boys and 28 girls) and 47 fourth-grade children (23 boys and 24 girls) recruited from two predominantly middle-class San Francisco Bay area schools. The third-grade children ranged in age from 8 years, 1 month to 10 years, 7 months ( $M = 9.1$  years;  $SD = 6.9$  months). The fourth-grade children ranged in age from 9 years, 1 month to 11 years, 4 months ( $M = 10.1$  years;  $SD = 6.5$  months).

### Standardized Measures

The raw scores from the Word Identification subtest of the Woodcock-Johnson Reading Mastery Tests (Woodcock, 1987) were used in the analyses that follow. Subjects also completed Raven Standard Progressive Matrices, (Psychological Corporation, 1978) a task tapping nonverbal problem-solving skills and commonly viewed as a measure of nonverbal intelligence. Raw scores were used in the analyses that follow.

### Phonological Processing Measures

*Phoneme deletion task.* In this task, the children were instructed to listen carefully to the initial sound of each word the experimenter pronounced. In the first part of the task, the subjects listened to ten words (smart, globe, spark, crib, strip, spot, trick, snipe, smack, and

stop) and were asked to remove the initial sound of the word and then say the remaining sound segment out loud (for example, to say "park" to the stimulus "spark"). The task differed from many similar tasks in the literature in that the initial phoneme was part of a blend. Subjects began with the three practice words *block*, *grab*, and *crown*. For the second set of ten words (just, craft, lard, drift, cork, tuft, depend, crust, best, and blast) the subject was asked to provide the sound segment that remained when the final phoneme was removed (for example, to say "blas" to the stimulus "blast"). The second set of ten words was preceded by the three practice words *heard*, *fork*, and *past*. Raw scores were used in the data analyses that follow. The maximum score possible was 20. The split-half reliability (odd-even, Spearman-Brown corrected) of the phoneme deletion task was .94.

*Phonological choice task.* The phoneme deletion task tapped the ability to deal with phoneme-sized sound segments. It did not implicate at all the ability to code the sound system from the orthography. In contrast, the phonological choice task was chosen in order to explicitly tap spelling-sound decoding skills. This task was adapted from the work of Olson, Kliegl, Davidson, and Foltz (1985). The subject viewed pairs of pseudowords (e.g., kake-dake, filst-ferst, bote-boaf, broave-braive) and indicated which pseudoword sounded like a real word when pronounced by pressing a button on the computer keyboard. Because the stimulus pairs are both nonwords, the only way to respond correctly is to recode the stimuli phonologically.

The stimuli were presented on a monochrome monitor under the control of an Apple II microcomputer, as described in Stanovich and West (1989). Subsequent to five practice trials, the subject received 25 experimental trials. The stimuli were taken from Table 2 of Olson et al. (1985). The median reaction times in milliseconds ( $M = 2,306$ ,  $SD = 1,235$ ) and the number of response errors ( $M = 8.7$ ,  $SD = 4.1$ ) were calculated by the computer. The split-half reliabilities (odd-even, Spearman-Brown corrected) of the time and error measures from this task were .93 and .64, respectively. Because an appreciable number of errors were made on this task, we computed a composite index combining both speed and accuracy scores. For each subject, the median reaction time for correct responses and the number of errors on the task were both converted to z-scores. These two z-scores were then averaged to form a composite index of overall performance on the phonological choice task.

A composite phonological processing score was also formed by combining performance on the phoneme deletion task and the phonological choice task. Each subject's performance on the phoneme deletion task was converted to a z-score, and this score was averaged with the summary z-score for the phonological choice task to form the phonological processing composite.

### Orthographic Processing Measures

*Orthographic choice task.* This task was also adapted from the work of Olson, Kliegl, Davidson, and Foltz (1985). The subject viewed pairs of letter strings that sounded alike (e.g., rume-room, snow-snoe, wrote-wroat, lurn-learn) and indicated which one was spelled correctly by pressing one of two buttons on the computer keyboard. Other aspects of the experimental procedure (timing, feedback, etc.) were identical to those used in the phonological choice task.

Subsequent to five practice trials, the subject received 25 experimental trials. The stimuli were selected from those displayed in Table 2 of Olson et al. (1985). Five of the twenty-five stimulus pairs had two syllables and the rest were one-syllable strings. The median reaction times in milliseconds ( $M = 1,285$ ,  $SD = 489$ ) and the number of response errors ( $M = 3.0$ ,  $SD = 3.1$ ) were calculated by the computer. The split-half reliabilities (odd-even, Spearman-Brown corrected) of the time and error measures from this task were .93 and .82, respectively. For each subject, the median reaction time for

correct responses and the number of errors on the task were both converted to z-scores. These two z-scores were then averaged to form a composite index of overall performance on the orthographic choice task.

*Homophone choice task.* In the homophone choice task, the experimenter read a question orally to the subject (e.g., "Which is a fruit?"). Immediately on pronouncing the last word in the question, the experimenter pressed a microswitch attached to the computer that simultaneously started the millisecond clock and presented two homophones side by side (e.g., pair-pear). The subject responded by pressing a key (z or /) on the computer keyboard to indicate which of the two homophones answered the question. The correct response was equally often on the left and right. Timing, feedback, and all other aspects of the experimental procedure were identical to those used in the phonological choice task.

Subsequent to five practice trials, the subject received 25 experimental trials. The stimuli were taken from the homophone norms published by Kreuz (1987). The pairs employed as experimental stimuli were rose-rows, tail-tale, ate-eight, cents-sense, flew-flu, none-nun, right-write, groan-grown, bare-bear, ant-aunt, flour-flower, one-won, plain-plane, sail-sale, pain-pane, hair-hare, poor-pour, blew-blue, deer-dear, hall-haul, pair-pear, stake-steak, week-weak, brake-break, and pray-prey. The median reaction times in milliseconds ( $M = 1,530$ ,  $SD = 522$ ) and the number of response errors ( $M = 6.5$ ,  $SD = 2.6$ ) were calculated by the computer. The split-half reliabilities (odd-even, Spearman-Brown corrected) of the time and error measures from this task were .82 and .59, respectively. For each subject, the median reaction time for correct responses and the number of errors on the task were both converted to z-scores. These two z-scores were then averaged to form a composite index of overall performance on the homophone choice task.

A composite orthographic processing score was also formed by combining performance on the orthographic choice task and the homophone choice task. Each subject's summary z-scores on the orthographic choice task and on the homophone choice task were averaged to form the orthographic processing composite score.

### *Paired Associate Memory Task*

The stimuli in this task were loosely adapted from the nonsense forms used by Gibson, Gibson, Pick, and Osser (1962). The stimuli were strings of nonsense forms (meaningless symbols) ranging in length from two to five forms. The symbol strings were named using commonly occurring words (turtle, lamp, train, kite, dog, snake, tree, boat, whale, pie, flower, ring, plate, shoe, bus, table, wasp, horse, shoe, and bell). There was no direct correspondence between the name and the number of forms in the string.

The subjects were told that they were going to be shown many cards with symbols printed on them and that they should remember what the symbols looked like and the name of the symbol string. Immediately following the presentation of the stimuli, the children were tested on their memory for the 20 forms and names. During the subsequent memory test phase, the children were shown 30 cards (the 20 previously seen nonsense form strings and 10 foils) one at a time. The subjects were first asked if they recognized each symbol string. If the child indicated they recognized the symbol string, they were asked to recall its name. Recognition performance failed to correlate with any other variable in the study; however, the number of stimuli correctly named did correlate with other experimental variables and thus is the measure used in subsequent analyses. The split-half reliability of this measure (Spearman-Brown corrected) was .50.

### *Print Exposure Measure: The Title Recognition Test*

The Title Recognition Test was constructed as an analog to the Author Recognition Test developed for use with adults (Stanovich & West, 1989). Both measures were explicitly designed to circumvent the problem of questionnaire contamination by tendencies toward socially desirable responses (Paulhus, 1984) and also the problem of contamination by inaccurate estimates of the time or frequency of reading activities.

The TRT consisted of a total of 39 items: 25 actual children's book titles and 14 foils for book names. The 25 titles were selected from a sample of book titles generated in pilot investigations with groups of children ranging in grade level from second grade through high school. In selecting the 25 items to appear on the TRT, we attempted to choose titles that were not prominent parts of classroom reading activities in these particular schools, because we wanted the TRT to probe out-of-school rather than school-directed reading. Of course, versions of the TRT constructed for other classrooms would necessarily differ somewhat in item content. The foils were generated by the authors and were randomly interspersed among the actual book titles.

The logic by which the TRT circumvents the social desirability and subjective response problems inherent in most reading exposure measures is a simple yet powerful one that borrows from signal detection theory. The tendency to have a low criterion for checking a name will result in the checking of foils as well as actual titles, and this tendency can be corrected for by adjusting the number of actual titles checked based on the number of foils checked.

The list of children's titles appearing on the TRT is presented in the Appendix along with the percentage recognition for each item. Also listed in the Appendix is the percentage recognition for 51 third- and fourth-grade students in a suburban school in Michigan who completed the TRT but not the other experimental tasks. These percentages allow for some assessment of the generality of the performance patterns on the TRT. The correlation between the percentage recognition of the items in the California and the Michigan samples was very high ( $r = .87$ ). The foil titles are separated in the Appendix, but on the actual TRT forms they were interspersed with the real titles.

It is clear that the TRT is a proxy measure of reading activity. It is obviously not intended to measure absolute levels of print exposure, as are the diary studies of children's activities (e.g., Anderson, Wilson, & Fielding, 1988; Greaney, 1980) that attempt to estimate actual time spent reading. Instead, the TRT was designed as a measure reflecting relative individual differences in exposure to print. Nevertheless, it is unclear just how much the TRT's obvious limitations impair its performance as a probe of environmental print exposure. For example, it is clear that to get credit for a correct item on the TRT one need only have some familiarity with the title. However, this seemingly problematic feature—that responses can be based on general familiarity rather than a more complete reading of the book—may not be quite the drawback it seems. Drawing attention to the possibility of responding on the basis of a shallow familiarity serves to emphasize the fact that the TRT is not cognitively demanding and that it does not load on memory as much as some other tasks in which children might be asked to volunteer titles or information about plot or characters. Requiring recall of children may fail to appropriately index books read so long ago that they are partially forgotten. Title recognition appropriately allows such imperfectly recalled items to influence the obtained print exposure score.

The TRT was administered to students as a group within each classroom. The students were told that the TRT contained the titles of books children their age commonly read and many foils—names of books that did not exist. The actual instructions that were read to the subjects and that were printed on their response sheets were as

follows: "Below you will see a list of book titles. Some of the titles are the names of actual books and some are not. You are to read the names and put a check mark next to the names of those that you know are books. Do not guess, but only check those that you know are actual books. Remember, some of the titles are not those of popular books, so guessing can easily be detected." On the response sheet that the subjects completed, this measure was labeled the *Title Recognition Questionnaire* and was referred to in this manner by the experimenter. Due to absences and school scheduling constraints, 18 subjects did not complete the TRT, leaving a total of 80 subjects (39 third graders and 41 fourth graders) for this measure. The TRT took approximately five minutes to administer.

For each subject, the number of correct targets identified ( $M = 8.7$ ,  $SD = 4.5$ ) was recorded, as well as the number of foils checked ( $M = 2.9$ ,  $SD = 3.1$ ). The reliability of the number of correct items checked was .81 (Cronbach's alpha). To take into account possible differential thresholds for guessing, a derived score was calculated for each subject that corrected the number of actual titles checked based on the number of foils checked. The correction was the traditional high threshold correction for guessing that has been applied in other paradigms (e.g., Anderson & Freebody, 1983; Graesser & Nakamura, 1982) where target stimuli must be detected in the context of foils:

$$\text{Probability of a correct detection} = [P(\text{hit}) - P(\text{false alarm})] / [1 - P(\text{false alarm})]$$

This derived score was used in the analyses that follow. Other corrections for guessing (see Snodgrass & Corwin, 1988) resulted in virtually identical correlational results.

### Procedure

Raven progressive matrices and the TRT were group administered to the children in their classrooms. The remaining tasks were individually administered to the subjects in one session that lasted approximately 45 minutes. Half of the subjects received the tasks in the following order: Woodcock Word Identification, phoneme deletion task, orthographic choice task, phonological choice task, homophone choice task, and paired-associate memory task. The other half of the subjects received the following ordering: orthographic choice task, phonological choice task, homophone choice task, Woodcock Word Identification, phoneme deletion task, and the paired-associate memory task.

### Results

In all the analyses that follow, the data from the children in the two grades will be combined to allow for a larger sample size and thus more powerful analyses. The performance of the children in these two adjacent grades was highly overlapping. Age in months was partialled out from the criterion variable in all the regression analyses that follow. All the relationships obtained in the larger sample were replicated in analyses conducted on the data within each grade level.

The correlations among all the major variables in the study, as well as the means and standard deviations, are displayed in Table 1. Correlations involving the TRT are based on a sample size of 80 and are significant at the .05 level (two-tailed) if greater than .22. Correlations involving all other variables are based on a sample size of 98 and are significant at the .05 level (two-tailed) if greater than .20. The phonological and orthographic z-score composites are represented, along with the two individual tasks that are contained within

each of the composites. All variables involving time and error measures have been reflected so that superior performance on all tasks is indicated by higher scores, thus simplifying the interpretation of the correlations in the matrix.

Table 1 indicates that performance on the Woodcock Word Identification subtest is significantly correlated with every variable in the study. Moderate correlations between this word recognition measure and performance on the two orthographic processing tasks, the phoneme deletion task, and the TRT were obtained, and there was a fairly high correlation between Woodcock Word Identification and the phonological choice task.

### *Can Orthographic Processing Ability Account for Unique Variance in Word Recognition?*

The critical questions of the study were addressed through a series of hierarchical regression analyses. Table 2 presents the results of several hierarchical regression analyses that addressed the question of whether orthographic processing skill accounts for variance in word recognition ability once phonological processing variance has been partialled out. The criterion variable in all the analyses is the raw score on the Woodcock Word Identification subtest, and in all analyses age in months is entered first in order to partial out the effects of that variable.

The first analysis indicates that although age and the two phonological processing tasks together accounted for substantial variance in word recognition ability (multiple  $R = .617$ ), performance on the orthographic choice task still accounted for significant additional variance. The second analysis indicates that the same is true of the homophone choice task. The third hierarchical regression analysis provides a very stringent test of whether orthographic processing ability is a unique predictor of variance in word recognition skill by partialling out age, general cognitive abilities, and phonological processing skill prior to entering the orthographic processing composite score. The nonspecific factors of age, performance on the Raven progressive matrices, and performance on the paired associate memory task had a multiple  $R$  of .429 with word recognition ability. The phonological processing score accounted for significant unique variance when entered next, bringing the multiple  $R$  to .622. Nevertheless, when the orthographic processing composite was entered subsequent to all of these measures, it accounted for an additional 10.2% of the variance in word recognition ability. The fourth hierarchical regression showed a basically similar result when the phonological task most highly correlated with word identification, the phonological choice task, replaced the phonological composite. Thus, the linkage between orthographic processing ability and word recognition skill seems not to be the result of spurious linkages between orthographic processing skill and either phonological abilities or nonspecific cognitive abilities.

There does seem to be variation in orthographic processing skill that is linked to word recognition ability and that is independent of phonological processes. The development of print-specific knowledge is not entirely parasitic on phonol-

Table 1  
Intercorrelations Among Variables in the Study

Variable	1	2	3	4	5	6	7	8	9	10
1. Woodcock Word Identification										
2. Title Recognition Test (TRT)	.37									
3. Phonological choice z-score	.59	.12								
4. Phoneme deletion task	.38	-.04	.38							
5. Orthographic choice z-score	.45	.18	.32	.11						
6. Homophone choice z-score	.46	.46	.49	.08	.56					
7. Phonological processing composite	.56	-.04	.78	.88	.24	.31				
8. Orthographic processing composite	.51	.37	.46	.11	.89	.88	.31			
9. Raven Standard Progressive Matrices	.36	.17	.38	.36	.21	.34	.45	.31		
10. Paired associate memory	.31	.30	.16	.16	.16	.25	.19	.23	.35	
<i>M</i>	64.5	.18	.0	14.7	.0	.0	.0	.0	30.8	3.2
<i>SD</i>	11.8	.16	.75	4.9	.80	.78	.73	.70	10.5	1.7

Note. Correlations involving the TRT are based on an *N* of 80 and are significant at the .05 level (two-tailed) if larger than .22. Correlations involving all other variables are based on an *N* of 98 and are significant at the .05 level (two-tailed) if larger than .20.

ological processing skill. This conclusion thus shifts attention to the question of what factors determine variation in these orthographic processing abilities.

#### *Can Variance in Orthographic Processing Ability Be Linked to Print Exposure Differences That Are Independent of Phonological Processing Skill?*

The first several hierarchical regression analyses presented in Table 3 examine the question of whether print exposure

Table 2  
Unique Orthographic Processing Variance After Phonological Processing Variance Is Partialled Out

Predictors	Multiple <i>R</i>	<i>R</i> <sup>2</sup> change
Woodcock Word Identification		
Regression 1		
Age	.100	.010
Phonological choice	.617	.371**
Phoneme deletion	.681	.083**
Orthographic choice		
Regression 2		
Age	.100	.010
Phonological choice	.617	.371**
Phoneme deletion	.656	.050**
Homophone choice		
Regression 3		
Age	.100	.010
Raven matrices	.370	.127**
Paired-associate memory	.429	.047*
Phonological composite	.622	.203**
Orthographic composite	.699	.102**
Regression 4		
Age	.100	.010
Raven matrices	.370	.127**
Paired-associate memory	.429	.047*
Phonological choice	.639	.224**
Orthographic composite	.699	.080**

Note. *N* = 98. \**p* < .05. \*\**p* < .01.

differences can account for variance in the quality of the orthographic lexicon, once phonological skill has been partialled out. The criterion variable in these analyses is the orthographic processing composite score. The first hierarchical regression indicates that after age and the phonological processing composite score have been entered into the regression equation, performance on the TRT accounts for a statistically significant 9.5% of additional variance in orthographic processing. The next two analyses demonstrate that this finding is not a spurious result of variance in TRT performance overlapping with memory or intelligence. The TRT accounted for significant unique variance in orthographic processing once age, Raven matrices performance, paired-associate memory, and phonological processing performance were partialled out from orthographic processing performance. The fourth hierarchical regression shows a basically similar result when the phonological task most highly correlated with orthographic processing, the phonological choice task, replaces the phonological composite.

The next analysis demonstrates that performance on the TRT accounts for unique variance in Woodcock Word Identification once age and phonological processing have been partialled out. The next two analyses show, as in the analyses of orthographic processing, that this is not an artifact of linkages with memory or general cognitive skills. The TRT accounts for substantial unique variance even after age, Raven matrices performance, paired-associate memory, and phonological processing performance were partialled out. The TRT is an impressively specific predictor of word recognition performance, accounting for 6.2% of additional variance. The last hierarchical regression shows a basically similar result when the phonological task most highly correlated with word identification, the phonological choice task, replaces the phonological composite. These two final hierarchical regressions are heavily biased against the TRT because they partial out so many other cognitive variables prior to entering the print exposure measure.

Table 3  
*Unique Print Exposure Variance After Phonological Processing Variance Is Partialled Out*

Predictors	Multiple R	R <sup>2</sup> change
Orthographic composite		
Regression 1		
Age	.017	.000
Phonological composite	.307	.094**
Title Recognition Test	.434	.095**
Regression 2		
Age	.017	.000
Raven matrices	.283	.080*
Phonological composite	.348	.041
Title Recognition Test	.445	.077**
Regression 3		
Age	.017	.000
Raven matrices	.283	.080*
Paired-associate memory	.307	.014
Phonological composite	.367	.041
Title Recognition Test	.460	.077**
Regression 4		
Age	.017	.000
Raven matrices	.283	.080*
Paired-associate memory	.307	.014
Phonological choice	.496	.152**
Title Recognition Test	.563	.071**
Woodcock Word Identification		
Regression 5		
Age	.069	.005
Phonological composite	.521	.266**
Title Recognition Test	.582	.068**
Regression 6		
Age	.069	.005
Raven matrices	.317	.096**
Phonological composite	.529	.179**
Title Recognition Test	.583	.060*
Regression 7		
Age	.069	.005
Raven matrices	.317	.096**
Paired-associate memory	.392	.053*
Phonological composite	.576	.177**
Title Recognition Test	.627	.062**
Regression 8		
Age	.069	.005
Raven matrices	.317	.096**
Paired-associate memory	.392	.053*
Phonological choice	.592	.197**
Title Recognition Test	.637	.055*

Note.  $N = 80$ . \*  $p < .05$ . \*\*  $p < .01$ .

### *Orthographic Processing As an Ability or Merely Print Exposure?*

Given that we have isolated variance in orthographic processing that is independent of phonological abilities and linked this orthographic variance to differences in exposure to print, one additional question that might be asked is whether we have now exhausted all the reliable orthographic variance. In short, does phonological processing ability and print exposure account for all the variance in orthographic processing skill that can be linked with word recognition?

There are grounds for believing that these two factors should not account for all the reliable orthographic processing variance. For example, consider the case of the good reader but poor speller (see Bruck & Waters, 1988, 1990; Frith, 1985). Anecdotal reports of this phenomenon usually stress the inefficacy of multiple exposures to troublesome words (e.g., the college professor who hesitates every time before spelling "recommendation" even though it is continually encountered in print; see Frith, 1980). At the same time, however, such individuals are claimed to have fluent decoding ability. The orthographic processing problems that plague such individuals are presumed not to result from phonological processing problems or from lack of print exposure. Thus, if we take these reports at face value, they predict that there should be reliable variation among individuals in orthographic processing even after variability in phonological processing and print exposure has been removed.

We used a hierarchical regression analysis to test this conjecture. The orthographic composite score was entered as a predictor of Woodcock Word Identification after age, phonological ability, and the TRT had been entered into the regression equation. Age and the phonological composite together yielded a multiple  $R$  of .521 and the TRT explained an additional 6.8% ( $p < .01$ ) of the variance. However, the orthographic composite, when entered last, accounted for a statistically significant 6.4% of the variance in Woodcock Word Identification performance. Thus, phonological processing ability and print exposure did not exhaust all the reliable variance in orthographic processing ability. Stanovich and West (1989) report a similar conclusion in a study of adult subjects.

### Discussion

The answer to our first question—whether orthographic processing ability accounts for word recognition skill independent of phonological processing skill—was answered in the affirmative. A variety of different analyses demonstrated that performance on orthographic processing tasks predicts word recognition skill after controlling for phonological processing ability in addition to memory and nonverbal intelligence. Our second question—whether orthographic processing differences that are independent of phonological ability can be linked to print exposure differences—was also answered in the affirmative. If orthographic processing differences were indirectly dependent on phonological processing abilities that directly cause print exposure variance, then print exposure differences should not account for orthographic variance once phonological skill has been partialled out. This prediction was repeatedly falsified in the data.

The results of our study and the results of Stanovich and West (1989) are convergent in an interesting way with the twin study of component subskills of word recognition reported by Olson, Wise, Conners, Rack, and Fulker (1989). They reported that the variance in word recognition associated with phonological processing had a sizable heritability, whereas the variance in word recognition associated with orthographic processing had a considerably lower heritability. Olson et al. (1989) pointed to differences in degree of print

exposure as one potential environmental determinant of the orthographic processing ability that determines reading skill. We have provided evidence that print exposure may indeed be creating environmentally-linked orthographic variance not tied to phonological processing differences.

The variance in reading ability that is linked to such environmental variables as reading volume has played an increasingly prominent role in recent theories of individual differences in reading. Several authors have emphasized that both in and out of school, readers of higher ability are progressively exposed to more print than are their less skilled peers, thus leading to an increasing divergence in the performance of skilled and less skilled readers (Allington, 1980, 1983, 1984; Anderson et al., 1988; Biemiller, 1977-1978; Juel, 1988; Nagy & Anderson, 1984; Nagy, Herman & Anderson, 1985; Stanovich, 1986, 1988b). As Nagy and Anderson have commented on their estimates of the differences in volume of reading between skilled and less skilled readers "there are staggering individual differences in the volume of language experience, and therefore, opportunity to learn new words" (p. 328).

It is likely that the TRT is a brief test that taps into these enormous differences in exposure to print outside of the classroom, and the results presented here indicate that such print exposure differences can have very specific effects on orthographic processing efficiency. Of course, orthographic processing skill that is honed by reading practice in turn leads to more efficient word recognition, which makes free reading more enjoyable, thus setting the stage for further reciprocal interactions that serve to magnify early achievement differences between children. Such "rich-get-richer" (and, conversely, "poor-get-poorer") effects are becoming of increasing concern to reading theorists (Anderson et al., 1988; Hayes, 1988; Hayes & Ahrens, 1988; Juel, 1988; Nagy & Anderson, 1984; Stanovich, 1986).

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## Appendix

### Title Recognition Test Items

Actual title	Percent identified		Foil	False alarm rate (%)	
	California sample	Michigan sample		California sample	Michigan sample
Jackaroo	11.2	3.9	Joanne	6.6	6.0
The Kid Who Only Hit Homers	30.0	47.1	It's My Room	11.3	7.9
Call of the Wild	30.0	45.1	Hot Top	8.6	4.0
The Chosen	10.0	5.9	Don't Go Away	9.3	6.0
Tales of a Fourth Grade Nothing	77.5	92.2	The Hideaway	13.2	8.6
Soup	17.5	15.7	The Missing Letter	23.2	18.5
The Secret Garden	76.2	51.0	The Rollaway	8.6	6.0
The Cybil War	38.7	17.6	Sadie Goes to Hollywood	11.9	16.6
Just Between Us	37.5	33.3	The Schoolhouse	11.9	10.6
Heidi	37.5	49.0	He's Your Little Brother!	13.2	10.6
Freedom Train	30.0	17.6	Ethan Allen	2.6	6.0
James & the Giant Peach	78.8	64.7	The Lost Shoe	15.2	10.6
Ballet Shoes	22.5	9.8	Skateboard	11.3	9.3
Superfudge	73.8	88.2	Curious Jim	7.3	6.0
Dr. Dolittle	50.0	37.3			
Strawberry Girl	18.8	13.7			
When Hitler Stole Pink Rabbit	23.7	13.7			
The Boxcar Children	32.5	29.4			
Becky's Horse	22.5	25.5			
The Great Coverup	18.8	7.8			
Misty of Chincoteague	18.8	15.7			
Henry and the Clubhouse	47.5	25.5			
Slammer	6.2	9.8			
Harriet the Spy	42.5	33.3			
Jabberwocky	7.5	15.7			

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