Mann, V. (in press). Phonological abilities: Effective predictors of future reading ability. In L. Rieben & C. A. Perfetti (Eds.), *Learning to read: Basic research and its implications*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition, 7,* 323–331.
Olson, D. R. (1977). From utterance to text: The bias of language in speech and writing. *Harvard Educational Review, 47,* 187–206.
Perfetti, C. A., (1977). Language comprehension and fast decoding: Some psycholinguistic prerequisites for skilled reading comprehension. In J. Guthrie (Ed.), *Cognition, curriculum and comprehension*. Newark, DE: International Reading Association.
Perfetti, C. A. (1984). Reading acquisition and beyond: Decoding includes cognition. *American Journal of Education, 93,* 43–60.
Perfetti, C. A. (1985). *Reading ability*. New York: Oxford University Press.
Perfetti, C. A. (1987). Language, speech and print: Some asymmetries in the acquisition of literacy. In R. Horowitz & S. J. Samuels (Eds.), *Comprehending oral and written language*. New York: Academic Press.
Perfetti, C. A. (in press). Representations and awareness in the acquisition of reading competence. In L. Rieben & C. A. Perfetti (Eds.), *Learning to read: Basic research and its implications*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
Read, C. (1986). *Children's creative spellings*. London: Routledge & Kegan Paul.
Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*.

17 Beyond Phonological Processes: Print Exposure and Orthographic Processing

Keith E. Stanovich
Ontario Institute for Studies in Education

Richard F. West
James Madison University

Anne E. Cunningham
University of California, Berkeley

It is appropriate for this particular volume to appear at this time, because Isabelle Liberman will shortly have conferred on her a high scientific honor—one conferred by the scientific process itself, rather than by formal professional or administrative bodies. It is the honor of having one's conceptual viewpoint become absorbed into the background assumptions of all current theories—and it is the most profound honor in science.

The evolution of knowledge in the area of reading acquisition is now at a stage that the contributions of Isabelle Liberman can best be seen in this light. She was the builder of the foundational assumptions about the importance of phonological processes that we now take for granted. Many of the contributors to this volume share certain assumptions about reading that were far from established when Isabelle began making her seminal contributions to our understanding of reading acquisition. Indeed, an outsider perusing this volume is perhaps in the best position to see the magnitude of her contribution. To the layperson, our refined disputes about precisely how to fractionate phonological abilities and to trace the causal paths of each component will seem, at best, arcane; whereas the background assumptions that we all share will stand out in bold relief. We must remember this point when communicating current research on phonological processes to educators and parents.

They should not mistake our disputes about highly specific issues for disagreements about foundational assumptions.

INDIVIDUAL DIFFERENCES IN WORD RECOGNITION BEYOND PHONOLOGICAL PROCESSING

The work that we describe thus begins by assuming the fundamental importance of phonological processes in word recognition. But it pays complement to this foundational assumption by trying to go beyond it. Several chapters in this volume describe attempts to refine theories of how phonological abilities are intertwined with reading acquisition. Our focus is somewhat different. We are attempting to locate the boundary conditions of the linkage between individual differences in phonological processing and reading acquisition.

The question is whether, despite the importance of phonological processing abilities in explaining variance in the acquisition of word recognition skill, there is another class of factors that could explain additional variance. This possibility is raised because even though the correlations between phonological processing skill and word recognition ability are quite high, they are considerably less than unity even after correction for attenuation (Stanovich, Cunningham, & Cramer, 1984; Wagner, 1988; Wagner & Torgesen, 1987; Yopp, 1988).

Additionally, Phil Gough, Bill Tunmer, and others 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 (Gough, Juel, & Griffith, in press; Juel, Griffith, & Gough, 1986; Tunmer & Nesdale, 1985); that is, whereas virtually no child with deficient phonological processing skills develops reading ability with ease, some children with adequate phonological sensitivity lag behind in the development of word recognition efficiency. If phonological processing is a necessary but not sufficient condition for the development of adequate word recognition skill, this implies that there may be another cognitive "sticking point" for some children—a second critical locus of variance in word recognition skill.

Some recent empirical research and theoretical speculation has raised the possibility that variance in the ability to form, store, and access orthographic representations accounts for some of the residual variance in word recognition skill not explained by phonological factors. Case studies of adults with acquired surface dyslexia (Patterson, Marshall, & Coltheart, 1985) have suggested that there exist reading problems specifically associated with difficulties in accessing and/or forming representations in the orthographic lexicon. Clinical studies of dyslexic children have also repeatedly suggested the existence of a subtype of poor readers with unique difficulties in dealing

with the visual representations of words (e.g., Bodor, 1973), although the interpretation of this clinical work is very equivocal (Hooper & Hynd, 1985; Olson, Kliegl, Davidson, & Foltz, 1985; Perfetti, 1985). Some studies of individual differences across the normal continuum of ability have suggested that children show marked differences in their tendency to utilize print-specific information when recognizing words (Baron & Treiman, 1980; Bryant & Impey, 1986; Freebody & Byrne, 1988; Treiman, 1984).

Some current theoretical views are also consistent with the idea of orthographic processing skill as an independent source of word recognition variance. For example, the three stages in Frith's (1985) model of reading acquisition are characterized by the development of logographic, alphabetic, and orthographic skill, respectively. Developmental arrest prior to or early in the alphabetic stage would lead to the most common type of poor reader: those with deficient phonological and spelling-to-sound decoding skills. Developmental arrest at the next stage results in reading problems more closely associated with orthographic processing problems. Frith's (1985) model, then, is consistent with the idea of phonological skills as necessary but not sufficient for the full development of word recognition fluency.

However, despite some convergent evidence for the idea of individual differences in orthographic processing skill, there are also some reasons to question the hypothesis of orthographic processing as an independent source of variance. For example, it is clearly the case that a child with efficiently functioning phonological coding processes will develop a richer orthographic lexicon due to a greater number of "positive learning trials" (Jorm & Share, 1983) with words; that is, instances where accurate decoding leads to the complete phonological representation of a word becoming associated with its visual form. Such positive learning trials lead to the amalgamation of orthographic and phonological representations in memory (Barron, 1986; Ehri, 1980,1984,1987), and the amalgamated orthographic representation is what eventually enables rapid and efficient processes of direct access to the lexicon.

Thus, there is little doubt that the development of orthographic processing skill must be somewhat dependent on phonological processing abilities. The critical question for research is whether the development of the orthographic lexicon is *entirely* parasitic on the operation of phonological processes. In short, does orthographic processing skill account for variance in word recognition and/or spelling ability once phonological processing skill has been partialled out? For example, Gough and colleagues (Gough et al., in press) argue that word-specific knowledge must be acquired in addition to spelling-sound connections, and that the development of the orthographic lexicon depends on factors in addition to phonological decoding skill. They point to the fact that children who are equally skilled at reading regular words vary considerably in their ability to read exception words. Gough et al. (in press) speculate that the ability to read exception words essentially depends on how much children practice their decoding skills.

This conjecture naturally raises the question of whether there are differences in exposure to print that are independent of phonological decoding skills. 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 child is at phonological coding. If this is the case, then orthographic processing differences could not serve as a unique source of reading variance. Such differences would be indirectly parasitic on the phonological processing abilities that directly cause print exposure variance. This conjecture yields the prediction that print exposure differences should not account for variance in the quality of the orthographic lexicon, once phonological skill has been partialled out.

In studies employing both adults and children we have attempted to address these two basic questions: First, can orthographic processing ability account for variance in word recognition and spelling once all the variance associated with phonological processing skill has been partialled out? Second, can orthographic processing variance be linked to print exposure differences that, again, are independent of phonological processing skill?

Can Orthographic Processing Ability Account for Unique Variance in Reading and Spelling?

In a multivariate study of college readers, we relied primarily on two tasks to partial out the phonological coding variance. One, not surprisingly, was a pseudoword naming task in which we employed stimuli previously used by Snowling (1985). These were pseudowords that had few or no analogy words (see Table 17.1), thus reducing the influence of pronunciation by analogy and rendering naming performance a purer index of small-unit spelling-sound decoding. The second task was the phonological choice task used previously by Olson et al. (1985) in their work with dyslexic children. Examples of the stimuli are given at the bottom of Table 17.1. The subject sees two nonwords side by side and indicates which sounds like a real word when pronounced by pressing one of two keys on a computer keyboard. Because the stimuli in the pairs are both nonwords, the only way to respond correctly is to phonologically recode the stimuli.

One of several measures of orthographic processing skill that we employed was again adapted from the work of Olson et al. (1985). In the orthographic choice task the subject views two letter strings that sound alike and indicates which one is spelled correctly by pressing a button on the keyboard. Examples of the stimuli are given at the bottom of Table 17.1. Because the two strings sound the same when decoded, differences in phonological coding ability cannot be the sole cause of performance differences on this task. Although

TABLE 17.1
Unique Orthographic Processing Variance After Phonological Coding Variance is Partialled Out: Adult Data ($N = 180$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2 change*
Composite Word Naming Performance		.700	.490**
		.746	.067**
Spelling: EST Critical Segments	Phonological Choice Pseudoword Naming	.456	.208**
	Orthographic Choice Homophone Choice	.546	.090**
Spelling: WRAT Critical Segments	Phonological Choice Pseudoword Naming	.504	.254**
	Orthographic Choice Homophone Choice	.546	.045**

**$p < .01$.

Examples of Stimuli:

Pseudoword Naming:
henk, kanth, vilp, nurm, romsig, baltrid

Phonological Choice Task:
bape - baik, leeve - meave, filst - ferst, floap - flote, shurt - shart, kard - carn

Orthographic Choice Task:
snoe - snow, turtle - tertle, face - fase, bowl - boal, wroat - wrote, scair - scare

Homophone Choice Task:

which is a number?	ate–eight
which is money?	cents–sense
which is an illness?	flew–flu
which is a woman?	none–nun
which is used for transportation?	plain–plane
which is done in water?	sail–sale

subjects might still use phonological recoding to determine what word the two strings map into, the task requires that a lexical representation be examined and thus to some extent should reflect the accessibility and/or quality of orthographic entries in the lexicon.

The second orthographic processing measure was a homophone choice task. Problems in processing homophones have consistently been viewed as characteristic of surface dyslexics who have specific difficulties accessing print-specific information (Patterson, Marshall, & Coltheart, 1985). Weaknesses in dealing with homophones would presumably characterize any reader with an imprecise orthographic lexicon. Therefore, a task indicative of homophone processing skill was developed. In our homophone choice task the experimenter read a question orally to the subject. Immediately upon pronouncing the last word in the question, the experimenter pressed a microswitch that caused the computer to present two homophones side by side on the screen. Examples of the stimuli are given at the bottom of Table 17.1. The subject simply indicates by pressing a button which of the two homophones answers the question.

In our initial study we employed adults as subjects. The stability and relative reliability of adult performance, coupled with our sample size of 180, allowed a reasonably fine-grained partitioning of variance. Table 17.1 presents the results of several hierarchical regression analyses by sets that address the question of whether orthographic processing skill accounts for variance in reading and spelling once phonological variance has been partialled out. All the predictor variables are z-score composites that combine both speed and accuracy on the task.

The first dependent variable is the composite performance on groups of regular, exception, and strange words taken from the work of Waters and Seidenberg (1985). The phonological tasks account for a large portion of variance in word naming, achieving a multiple R of .70. Nevertheless, the two orthographic tasks, when entered as a set, account for significant additional variance. The next two regressions demonstrate that the same thing holds for two spelling measures. The first is the ability to spell the critical segments on words taken from the Experimental Spelling Test developed by Fischer, Shankweiler, and Liberman (1985). The critical segments are phonologically opaque to varying degrees. The next spelling measure is the ability to spell critical segments on the WRAT-II. Pennington and associates (Pennington et al., 1986) have previously investigated the ability to spell these segments, which vary in sound-spelling ambiguity. Both regressions indicate that the orthographic tasks account for significant unique variance. Thus, in these adult data, for both word recognition and spelling, there are consistent indications that orthographic processing skill can be a significant predictor independent of the level of phonological skill.

Table 17.2 presents a parallel set of analyses conducted on the data from a multivariate study of third- and fourth-grade children. The criterion variable here is performance on the Word Identification subtest of the Woodcock Reading Mastery Tests. The phonological choice, orthographic choice, and homophone choice tasks were administered just as in the adult study. The pseudoword naming task was replaced in these analyses with a phoneme deletion task. The task was made appropriately difficult for these children by requiring the deletion of phonemes from consonant blends and by varying word position. The first two regression analyses indicate that despite the fact that the two phonological processing tasks accounted for a large portion of the word recognition variance—multiple R = .61—each of the

TABLE 17.2
Unique Orthographic Processing Variance After Phonological Coding Variance is Partialled Out: Third and Fourth Graders ($N = 98$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2-change*
Woodcock			
Word Identification		.611	.373**
		.671	.077**
Woodcock	Phonological Choice		
Word Identification	Phoneme Deletion	.611	.373**
	Homophone Choice	.650	.049*
Woodcock	Phonological Composite	.509	.259**
Word Identification	Orthographic Composite	.615	.118**

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

orthographic processing tasks accounted for significant unique variance. The last regression indicates essentially the same thing in an analysis that employed phonological and orthographic z-score composites of the respective pairs of tasks.

Thus, our studies of children and adults gave an affirmative answer to the first question. There does seem to be variation in orthographic processing skill that is linked to reading and spelling ability that is independent of phonological processing skill. The development of print-specific knowledge is not entirely parasitic on phonological 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?

As previously mentioned, Gough and colleagues (Gough et al., in press) have hypothesized that exposure to print is a mediating factor in the acquisition of the orthographic lexicon. Reinforcing interest in print exposure as a variable is the result of the twin studies of the component subskills of word recognition reported by Olson, Wise, Conners, and Rack (1990). In their studies of dyslexic readers they obtained results indicating that the variance in word recognition associated with phonological processing had a sizeable heritability, whereas the variance in word recognition associated with orthographic processing was much lower. Olson et al. (1990) pointed to differences in amount of print exposure as one potential environmental determinant of the orthographic processing ability that is linked to reading skill. In both our studies we addressed the issue of whether variance in orthographic processing that is not associated with phonological ability can be linked to differences in print exposure.

Measuring Print Exposure: The Author Recognition Test. Deriving an accurate and reliable measure of print exposure is a very difficult problem that only a few investigators have worked on. Both the two major methods that have been used—diary techniques and standard questionnaire techniques—have serious flaws. Standard questionnaire techniques involving multiple-choice and open-ended probes of reading habits produce data of low reliability when used with children and when used with adults are strongly contaminated by tendencies toward socially desirable responding (Paulhus, 1984). Diary techniques, though often more reliable (see Anderson, Wilson, & Fielding, 1988), require an extended cooperation and commitment on the part of subjects that simply may not be attainable for many investigators. Furthermore, diary techniques are still loaded with social desirability confounds when used with adults. This problem is particularly acute in cases like the present one where relatively educated people are being asked questions about a socially valued activity such as reading. National and local campaigns stressing the importance and social value of reading only exacerbate the social desirability problems surrounding such measures.

Thus, in addition to utilizing these traditional methods, we attempted to develop a proxy indicator of print exposure that was very simple to administer and that was not subject to social desirability confounds. The adult measure is called the Author Recognition Test (ART), and it requires the subject to scan a list of names containing well-known authors and writers and to simply check those that they know to be authors. What prevents the subjects from simply checking names that they really do not know? The names of the authors are embedded among the names of foils, and the subjects are informed of the existence of foils. In essence, the ART has a signal detection logic. Although checklist procedures have been used before to assess print exposure (Chomsky, 1972), they have not been employed in the context of a detection-type method that uses foils to control for differential response criteria. The foils discourage indiscriminate item checking and also allow the number of targets checked to be corrected for differential criterion effects. In the data presented here, the subject's score is corrected by subtracting the number of foils checked (Snodgrass & Corwin, 1988), but other scoring systems produce virtually identical correlational results. We have data indicating that the ART is a more valid and reliable indicator of print exposure than other types of questionnaire techniques. A converging measure, the Magazine Recognition Test was also utilized but is not emphasized here (see Stanovich & West, 1989).

The version of the Author Recognition Test (or ART) we used in this study contained 100 names, 50 actual popular authors and 50 foils. The list 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 volumes. The foil names were taken from the list of the editorial board of the 1987 volume of Reading Research Quarterly. It was thought a safe assumption that no one would consider these individuals to be popular writers; although Peter Bryant, the foil most often checked by our sample, would appear to have a good start on a literary career.

The ART has the obvious disadvantage of being an indirect measure of reading habits. It does not attempt to measure absolute levels of print exposure, as in some of the diary studies that have attempted to estimate the average minutes spent in literacy activities (Anderson et al., 1988; Greaney, 1980; Sharon, 1973–1974). The ART was instead designed as a measure reflecting relative individual differences in exposure to print. However, for specifically the latter purpose, the ART provides a more valid measure than other methods (see Stanovich & West, 1989), probably because it circumvents the social desirability problems inherent in most reading exposure measures. The relationships we have obtained with it are stronger than those typically obtained with more standard questionnaire methods (Nell, 1988; Walberg & Tsai, 1984).

The first several regression analyses reported in Table 17.3 examine the question of whether print exposure differences can account for variance in the quality of the orthographic lexicon, once phonological skill has been partialled out. Performance on the ART accounts for significant variance in the orthographic choice and homophone choice tasks after the variance due to phonological processing has been extracted. Similarly, the ability to spell the ambiguous segments on both of the spelling tests is significantly predicted by print exposure once phonological variance has been removed.

The fifth through the eighth analyses demonstrate that the unique word recognition variance predicted by the ART appears to be greater for words with less regular spelling-sound correspondences. The ART predicts significant additional variance in performance on exception and strange words (see Waters & Seidenberg, 1985), but not for regular words. This pattern is consistent with the conjecture that the formation of precise lexical representations, more important for the recognition of irregular words, is partially dependent on the amount of exposure to print. Finally, the next to the last analysis indicates that the ART accounts for a hefty amount of unique variance on the Woodcock Word Identification subtest. The last analysis stacks the deck even stronger against the ART by including a third measure of phonological coding ability, the number of nonphonological spelling

TABLE 17.3
Unique Print Exposure Variance After Phonological Coding Variance is Partialled Out: Adult Data ($N = 180$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2 change*
Orthographic Choice	Phonological Choice		
	Pseudoword Naming	.362	.131**
	Author Recognition Test	.416	.042**
Homophone Choice	Phonological Choice		
	Pseudoword Naming	.333	.111**
	Author Recognition Test	.406	.054**
Spelling:	Phonological Choice		
WRAT Critical Segments	Pseudoword Naming	.504	.254**
	Author Recognition Test	.560	.059**
Spelling:	Phonological Choice		
EST Critical Segments	Pseudoword Naming	.456	.208**
	Author Recognition Test	.483	.026*
Regular Word Naming	Phonological Choice		
	Pseudoword Naming	.577	.333**
	Author Recognition Test	.588	.013
Exception Word Naming	Phonological Choice		
	Pseudoword Naming	.587	.345**
	Author Recognition Test	.621	.040**
Strange Word Naming	Phonological Choice		
	Pseudoword Naming	.657	.431**
	Author Recognition Test	.697	.054**
Woodcock	Phonological Choice		
Word Identification	Pseudoword Naming	.553	.306**
	Author Recognition Test	.641	.105**
Woodcock	Phonological Choice		
Word Identification	Pseudoword Naming		
	Nonphonological Spelling	.604	.365**
	Author Recognition Test	.671	.086**

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

errors. Even though the phonological measures are allowed ample opportunity to capitalize on chance, the ART accounts for a statistically significant 8.6% of unique variance.

We have developed a logically analogous measure of print exposure for children, employing book titles rather than author names. The Title Recognition Test (TRT) requires the children to scan a list of popular children's

titles and check those that they recognize. Again, the presence of foils discourages guessing and allows the correction of the scores for differential criteria.

The first analysis in Table 17.4 presents the data from our children's sample using an orthographic composite score—a z-score combination of orthographic choice and homophone choice performance—as the criterion variable. The phonological variance is partialled first, using a z-score composite of performance on the phoneme deletion task and phonological choice task. The TRT accounts for substantial orthographic variance once the phonological variance has been removed. The next analyses test whether this initial finding is in any way an artifact of differences in intelligence or memory. The TRT accounts for substantial unique orthographic variance even after the phonological variance, performance on the Raven Progressive Matrices, and performance on a paired-associate memory task have been partialled. The next three analyses show that a similar pattern holds for performance on the Woodcock Word Identification subtest. The TRT is an impressively unique

TABLE 17.4
Unique Print Exposure Variance After Phonological Coding Variance is Partialled Out: Third and Fourth Graders ($N = 80$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2 change*
Orthographic Composite	Phonological Composite	.306	.094**
	Title Recognition Test	.429	.090**
Orthographic Composite	Raven	.282	.080*
	Phonological Composite	.348	.041
	Title Recognition Test	.438	.071*
Orthographic Composite	Paired-Associate Memory	.204	.049
	Raven	.307	.052*
	Phonological Composite	.366	.040
	Title Recognition Test	.451	.069*
Woodcock	Phonological Composite	.503	.253**
Word Identification	Title Recognition Test	.596	.102**
Woodcock	Raven	.312	.097**
Word Identification	Phonological Composite	.514	.167**
	Title Recognition Test	.596	.092**
Woodcock	Paired-Associate Memory	.306	.094**
Word Identification	Raven	.381	.051*
	Phonological Composite	.553	.161 **
	Title Recognition Test	.629	.089**

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

predictor of word recognition performance, accounting for 8.9% unique variance in this last analysis.

In summary, both the analyses of the adult data and the data from the third and fourth graders converged to answer the second of our research questions. If orthographic processing differences are 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. This prediction appears to have been falsified in the data of both samples. There were several indications in the data that there are orthographic processing differences associated with print exposure variation that are not directly linked to phonological recoding skills. If print exposure differences simply tracked how skilled the readers were at phonological coding, then the ART and TRT could not serve as a unique predictor of variance in orthographic processing.

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 reading and spelling?

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/poor-speller (see Bruck & Waters, 1988, in press; 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.

The analyses in Table 17.5 provide a stringent test of this conjecture. Three tasks are employed to first extract the phonological processing variance, then both the ART and the Magazine Recognition Test are used to extract the variance associated with print exposure. The first two analyses indicate that

TABLE 17.5
Unique Orthographic Processing Variance After Phonological Coding and Print Exposure Variance is Partialled Out: Adult Data ($N = 180$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2 change*
	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	604	.365**
	Author Recognition Test		
	Magazine Recognition Test	.677	.094**
	WRAT Critical Segments	.735	.081**
Composite Word Naming Performance	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	714	.510**
	Author Recognition Test		
	Magazine Recognition Test	744	.044**
	WRAT Critical Segments	759	.021*
Composite Word Naming Performance	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	.714	.510**
	Author Recognition Test		
	Magazine Recognition Test	744	.044**
	Orthographic Choice Task	769	.038**
Spelling: WRAT Critical Segments	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	.625	.391**
	Author Recognition Test		
	Magazine Recognition Test	.657	.041**
	EST Critical Segments	.751	.132**
Spelling: EST Critical Segments	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	.548	.301**
	Author Recognition Test		
	Magazine Recognition Test	562	.015
	Homophone Choice Task	594	.037**
Homophone Choice Task	Phonological Choice		
	Pseudoword Naming		
	Nonphonological Spelling	434	188**
	Author Recognition Test		
	Magazine Recognition Test	.492	.064**
	Orthographic Choice	.645	.174**

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

the ability to spell irregular word segments predicts Woodcock Word Identification performance and composite word naming performance, independent of phonological processing skill and print exposure differences. The third analysis indicates that the orthographic choice task is a unique predictor of composite word naming performance. The fourth analysis demonstrates that there is reliable variance remaining in the ability to spell irregular word segments after print exposure differences and phonological skill are accounted for, as the phenomenon of the good-reader/poor-speller would suggest. The fifth analysis demonstrates that the ability to spell irregular segments is independently predicted by a laboratory measure of orthographic processing with quite different task requirements: the homophone choice task. Finally, the orthographic choice task accounts for substantial unique variance in the homophone choice task. Table 17.6 indicates that, for the children too, orthographic processing is a unique predictor of performance on the Woodcock Word Identification subtest. These results consistently indicate that variability in phonological processing skill and differences in print exposure do not exhaust the reliable variance in orthographic processing.

We have made some initial attempts to analyze this independent orthographic variance but have been largely unsuccessful. For example, performance on a visual memory task was not related to the residualized orthographic variance. Likewise, Olson et al. (1990) failed to relate visual search performance to orthographic coding in their dyslexic sample and concluded: "These null results are consistent with Vellutino's (1979) point that visual-perceptual deficits are not a significant causal factor in reading disability, even for the component of word recognition that might plausibly be associated" (p. 299). Rather than looking in the visual domain for the underlying sources of orthographic processing ability differences, it may be more fruitful to pursue Frith's (1980, 1985) hypothesis that such problems may result from a habitual shallow and nonanalytic processing style when encountering words. For example, it might be informative to examine the performance of individuals with orthographic processing problems but without phonological coding difficulties or inadequate print exposure on refined measures of contextual

TABLE 17.6
Unique Orthographic Processing Variance After Phonological Coding and Print Exposure Variance is Partialled Out: Third and Fourth Graders ($N = 80$)

Dependent Variable	*Predictors*	*Multiple R*	*R^2 change*
Woodcock Word Identification	Phonological Composite		
	Title Recognition Test		
	Orthographic Composite		

$^{*}p < .05$.
$^{**}p < .01$.

facilitation of word recognition (Stanovich, 1986; Stanovich, Nathan, West, & Vala-Rossi, 1985; Stanovich & West, 1983).

SUMMARY

The results of our studies converge in an interesting way with the twin studies of component subskills of word recognition reported by Olson et al. (1990). Those investigators demonstrated that the linkage between phonological skill and word recognition ability in a dyslexic sample seemed to have a high heritability, whereas the linkage between orthographic processing ability and word recognition skill in the dyslexic children seemed to be due to largely nonheritable factors. Olson et al. (1990) pointed to differences in the amount of print exposure as one potential environmental determinant of the orthographic processing abilities linked to reading skill. We have provided evidence that print exposure may indeed be creating environmentally linked orthographic variance not tied to the (possibly heritable) phonological processing differences. Further research is needed to elucidate the nature of orthographic processing differences that cannot be linked to print exposure.

In this and further studies on print exposure that we are carrying out, we hope to at least partially specify the boundaries of influence of the phonological processing skills that are now the foundation of theorizing about individual differences in reading acquisition—a foundation built in large part on the seminal and original work of Isabelle Liberman.

REFERENCES

Anderson, R. C., Wilson, P. T., & Fielding, L. G. (1988). Growth in reading and how children spend their time outside of school. *Reading Research Quarterly, 23*, 285–303.

Baron, J., & Treiman, R. (1980). Use of orthography in reading and learning to read. In J. F. Kavanagh & R. L. Venezky (Eds.), *Orthography, reading, and dyslexia* (pp. 171–189). Baltimore: Park Press.

Barron, R. (1986). Word recognition in early reading: A review of the direct and indirect access hypothesis. *Cognition, 24*, 93–119.

Bodor, E. (1973). Developmental dyslexia: A diagnostic approach based on three atypical reading-spelling patterns. *Developmental Medicine and Child Neurology, 16*, 375–389.

Bruck, M., & Waters, G. (1988). An analysis of the spelling errors of children who differ in their reading and spelling skills. *Applied Psycholinguistics, 9*, 77–92.

Bruck, M., & Waters, G. (in press). An analysis of the component reading and spelling skills of good readers–good spellers, good readers–poor spellers, and poor readers–poor spellers. In T. Carr & B. A. Levy (Eds.), *Reading and its development: Component skills approaches*. New York: Academic Press.

Bryant, P., & Impey, L. (1986). The similarities between normal readers and developmental and acquired dyslexics. *Cognition, 24*,121–137.

Chomsky, C. (1972). Stages in language development and reading exposure. *Harvard Educational Review, 42,*1–33.

Ehri, L. C. (1980). The development of orthographic images. In U. Frith (Ed.), *Cognitive processes in spelling.* London: Academic Press.

Ehri, L. C. (1984). How orthography alters spoken language competencies in children learning to read and spell. In J. Downing & R. Valtin (Eds.), *Language awareness and learning to read* (pp. 119–147). New York: Springer-Verlag.

Ehri, L. C. (1987). Learning to read and spell words. *Journal of Reading Behavior, 19,* 5–31.

Fischer, F. W., Shankweiler, D., & Liberman, I. Y. (1985). Spelling proficiency and sensitivity to word structure. *Journal of Memory and Language, 24,* 423–441.

Freebody, P., & Byrne, B. (1988). Word-reading strategies in elementary school children: Relations to comprehension, reading time, and phonemic awareness. *Reading Research Quarterly, 23,* 441–453.

Frith, U. (1980). Unexpected spelling problems. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 495–515). London: Academic Press.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, J. Marshall, & M. Coltheart (Eds.), *Surface dyslexia* (pp. 301–330). London: Lawrence Erlbaum Associates.

Gough, P., Juel, C., & Griffith, P. (in press). Reading, spelling, and the orthographic cipher. In P. Gough, L. Ehri, & R. Treiman (Eds.), *Reading acquisition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Greaney, V. (1980). Factors related to amount and time of leasure time reading. *Reading Research Quarterly, 15,* 337–357.

Hooper, S., & Hynd, G. (1985). Differential diagnosis of subtypes of developmental dyslexia with the Kaufman Assessment Battery for Children. *Journal of Clinical Child Psychology, 14,*145–152.

Jorm, A., & Share, D. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics, 4,*103–147.

Juel, C., Griffith, P. L., & Gough, P. B. (1986). Acquisition of literacy: A longitudinal study of children in first and second grade. *Journal of Educational Psychology, 78,* 243–255.

Nell, V. (1988). The psychology of reading for pleasure: Needs and gratification. *Reading Research Quarterly, 23,* 6–50.

Olson, R., Kliegl, R., Davidson, B., & Foltz, G. (1985). Individual and developmental differences in reading disability. In T. Waller (Ed.), *Reading research: Advances in theory and practice* (Vol. 4, pp. 1–64). London: Academic Press.

Olson, R., Wise, B., Conners, F., & Rack, J. (1990). Organization, heritability, and remediation of component word recognition and language skills in disabled readers. In T. Carr & B. A. Levy (Eds.), *Reading and its development: Component skills approaches* (pp. 261–322). New York: Academic Press.

Patterson, K., Marshall, J., & Coltheart, M. (1985). *Surface dyslexia.* London: Lawrence Erlbaum Associates.

Paulhus, D. L. (1984). Two-component models of socially desirable responding. *Journal of Personality and Social Psychology, 46,* 598–609.

Pennington, B. F., McCabe, L. L., Smith, S., Lefly, D., Bookman, M., Kimberling, W., & Lubs, H. (1986). Spelling errors in adults with a form of familial dyslexia. *Child Development, 57,*1001–1013.

Perfetti, C. A. (1985). *Reading ability.* New York: Oxford University Press.

Sharon, A. T. (1973–1974). What do adults read? *Reading Research Quarterly, 9,* 148–169.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 34–50.

Snowling, M. (1985). The assessment of reading and spelling skills. In M. Snowling (Ed.), *Children's written language difficulties* (pp. 80-95). Windsor, England: NFER-Nelson.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21,* 360–407.

Stanovich, K. E., Cunningham, A. E., & Cramer, B. (1984). Assessing phonological awareness in kindergarten children: Issues of task comparability. *Journal of Experimental Child Psychology, 38,*175–190.

Stanovich, K. E., Nathan, R. G., West, R. F., & Vala-Rossi, M. (1985). Children's word recognition in context: Spreading activation, expectancy, and modularity. *Child Development, 56,*1418–1429.

Stanovich, K. E., & West, R. F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General, 112,*1–36.

Stanovich, K. E., & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly, 24,* 402–433.

Treiman, R. (1984). Individual differences among children in reading and spelling styles. *Journal of Experimental Child Psychology, 37,* 463–477.

Tunmer, W. E., & Nesdale, A. R. (1985). Phonemic segmentation skill and beginning reading. *Journal of Educational Psychology, 77,* 417–427.

Vellutino, F. (1979). *Dyslexia: Theory and research.* Cambridge, MA: MIT Press.

Wagner, R. K. (1988). Causal relations between the development of phonological processing abilities and the acquisition of reading skills: A meta-analysis. *Merrill-Palmer Quarterly, 34,* 261–279.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101,* 192–212.

Walberg, H. J., & Tsai, S. (1984). Reading achievement and diminishing returns to time. *Journal of Educational Psychology, 76,* 422–461.

Waters, G., & Seidenberg, M. (1985). Spelling-sound effects in reading: Time-course and decision criteria. *Memory & Cognition, 13,* 667–672.

Yopp, H. K. (1988). The validity and reliability of phonemic awareness tests. *Reading Research Quarterly, 23,* 169–177.