Multiple Orthographic Codes in Reading and Writing Acquisition\textsuperscript{1,2,3,4}

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ABSTRACT: A modified Stroop Test (single-letter, letter-cluster, and whole-word color-inconsistent stimuli) showed greater interference for the more automatic orthographic coding unit — the word — than for the less automatic coding units — single letters and letter-clusters — in developing readers in second, fourth, and sixth grade ($N = 72$, Study 1). A developmental trend was observed from relative skill in word-level orthographic-phonological correspondence in second graders to relative skill in subword level orthographic-phonological correspondences in sixth graders. A previous finding that whole word coding $> $ letter coding $> $ letter cluster coding in relative rate of development was replicated ($N = 300$, Study 2). Multiple orthographic codes — for whole words, single letters, and letter clusters — were correlated with both reading and writing but patterns of correlations with the component reading and writing skills changed from first to third grade; by third grade whole word coding was not correlated with reading and writing skills but letter cluster coding was correlated with all reading and most writing skills. Cue validity — categorization of letters on the basis of differentiating rather than distinctive features — improved from second to sixth grade and may account for developmental gains in letter cluster coding. Level of cue validity was correlated with speed of sentence comprehension ($N = 60$, Study 3). The theoretical and practical significance of multiple orthographic codes for orthographic-phonological connections in word recognition and for literacy acquisition in general is discussed.

KEYWORDS: Orthography, Reading Acquisition, Writing Acquisition, Stroop Test, Orthographic-Phonologic Correspondence

MULTIPLE ORTHOGRAPHIC CODES IN READING AND WRITING ACQUISITION

Processing visual (orthographic) information from the printed page is essential to reading (Adams, 1990). Yet, during the past decade, orthographic processing has received less research attention in comparison to phonological processing, which has been widely studied (e.g., see review by Wagner and Torgensen, 1987).

Orthographic processing has not always been neglected. For example, Mason (1975) showed that spatial redundancy is important in synthesizing letters within a word and that some poor readers may not utilize this source of orthographic information effectively. Rayner (1976) found that initial letters became less important and shape cues — defined as distinctive features of all the letters in a word and not as overall gestalt — became more important as reading skill improved. Venetzky and Massaro
(1979) argued, based on their and others' research, that automatic word recognition may depend on abstraction, through repeated exposure to written words, of orthographic regularity as to which letter or letter sequences typically occur at different word positions; they pointed out that orthographic regularity is not the same as letter-sound regularity in that words could be orthographically regular, but phonically irregular (e.g., eighth) or orthographically irregular but phonically regular (e.g., ssilf). Likewise, Glushko (1979) reasoned that words should be classified not only as regular or exception words with regard to phonics rules but also with regard to orthographic patterns and demonstrated regularity effects for orthographically consistent analogies (e.g., gave) compared to orthographically inconsistent analogies (e.g., have) for target words (e.g., wave). Sloboda (1977) and Johnson (1979) showed that word-level decisions are made faster than component-level decisions. Ehri (1980a, 1980b) introduced the term *orthographic image* to refer to the representation of a word's spelling in memory and reported converging evidence for the psychological reality of orthographic images (Ehri and Wilce, 1979, 1982, 1987; Ehri, 1980a). Many studies established that readers process letter information in detail rather than merely sampling it in connected text (for reviews, see Adams, 1990; Stanovich, 1986).

After the relative lull, research on orthographic processing is timely for at least three reasons. First, Adam's review of the literature on reading acquisition suggested that four processors are functionally interrelated in learning to read: an orthographic processor, which perceives letters in text; a phonological processor, which maps letters onto their spoken equivalents; a meaning processor, which contains knowledge of word meaning; and a context processor, which constructs on-going understanding of text. If an orthographic processor is involved, then it is of interest to unpack the details of its operation. Second, recent work by Stanovich, West, and Cunningham (in press) and by Olson, Wise, Conners, and Rack (in press) suggests that orthographic processes may be affected by environmental experiences. If so, then it is important to understand orthographic processes in greater detail so we can intervene if these processes are not developing normally. Third, the field seems to be moving from a focus on phonological processes alone to a focus on orthographic-phonological correspondences (e.g., Berninger, 1985, 1986, 1990; Berninger, Chen, and Abbott, 1988; Seidenberg, and McClelland, 1987, 1989; Van Orden, Pennington, and Stone, 1990).

**Operations of the orthographic processor.** One function of this processor may be to code the incoming stimulus word. Codes are procedures for transforming stimulus information into unitary mental representations; they are content-free and not the same as the information they represent, but may be governed by rules or specific cases (Johnson, 1978). Berninger (1987, Study 2) used an orthographic coding task that did not require