



Original Articles

Incidental orthographic learning during a color detection task



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ABSTRACT

Orthographic learning refers to the acquisition of knowledge about specific spelling patterns forming words and about general biases and constraints on letter sequences. It is thought to occur by strengthening simultaneously activated visual and phonological representations during reading. Here we demonstrate that a visual perceptual learning procedure that leaves no time for articulation can result in orthographic learning evidenced in improved reading and spelling performance. We employed task-irrelevant perceptual learning (TIPL), in which the stimuli to be learned are paired with an easy task target. Assorted line drawings and difficult-to-spell words were presented in red color among sequences of other black-colored words and images presented in rapid succession, constituting a fast-TIPL procedure with color detection being the explicit task. In five experiments, Greek children in Grades 4–5 showed increased recognition of words and images that had appeared in red, both during and after the training procedure, regardless of within-training testing, and also when targets appeared in blue instead of red. Significant transfer to reading and spelling emerged only after increased training intensity. In a sixth experiment, children in Grades 2–3 showed generalization to words not presented during training that carried the same derivational affixes as in the training set. We suggest that reinforcement signals related to detection of the target stimuli contribute to the strengthening of orthography-phonology connections beyond earlier levels of visually-based orthographic representation learning. These results highlight the potential of perceptual learning procedures for the reinforcement of higher-level orthographic representations.

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1. Introduction

Orthographic knowledge refers to information about representing spoken language in written form. It includes stored representations of specific written words and word parts as well as knowledge of general patterns governing speech sound representation and constraints on letter use (Apel, 2011). Literacy development depends on orthographic knowledge for efficient word recognition and spelling (Apel, 2009). The acquisition of orthographic knowledge has been studied focusing primarily on the initial registration and recognition of novel, i.e., previously unknown, letter strings, corresponding either to pseudowords or to orally known words. Less attention has been paid to the strengthening

of potentially existing orthographic representations of known words that may be too weak to permit fluent reading and accurate spelling.

In the present study we are concerned with the role of a necessary but neglected aspect of orthographic representation learning, namely visual perceptual processing. Visual processes mediate orthographic input prior to the activation of phonological or other aspects of lexical knowledge, therefore their efficiency can be expected to have downstream effects in higher-level orthographic representations. In particular, we examine the hypothesis that reinforcing visual processing of specific words will also enhance their orthographic representation beyond early perceptual processing. To reinforce word representations we apply an incidental perceptual learning procedure that requires no conscious effort directed at orthographic processing itself. If successful, the procedure should result in improved reading and spelling of the trained words.

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1.1. Orthographic learning

The origin and the nature of orthographic learning are of crucial importance but remain poorly understood (see reviews in [Castles & Nation, 2006, 2008](#); [Nation & Castles, 2017](#); [Share, 2008b](#)). Exposure to print is associated with enhanced word recognition performance ([Chateau & Jared, 2000](#)), suggesting a crucial role of reading experience in reading efficiency. However, it is not clear what is involved in the self-optimization of the reading processes. It has been established that co-activation of orthographic and phonological representations, that is, pronouncing or hearing the visually presented words, plays a crucial role in the formation of links between orthographic and phonological representations that underlie skilled reading and spelling ([Ehri, 2005](#); [Share, 1999, 2004, 2008b](#)). Orthographic learning also occurs with silent reading ([Bowey & Muller, 2005](#); [de Jong, Bitter, van Setten, & Marinus, 2009](#); [de Jong & Share, 2007](#)), highlighting the role of print exposure while upholding a crucial role for phonological involvement through “inner speech” processes.

Notably, studies of orthographic learning to date have focused almost exclusively on the—ecologically justified—case of learning via reading. That is, participants, typically young children, are asked to read (aloud or silently) the critical items, either in isolation or embedded in meaningful sentence contexts (e.g., [de Jong & Share, 2007](#); [Nation, Angell, & Castles, 2007](#)). A lexical decision task has also been used in a few studies (e.g., [de Jong et al., 2009](#)). Either way, children’s attention is explicitly drawn to the critical items, that is, the novel letter strings, by means of a deliberate act of reading, actively involving some form of conscious phonological decoding. However, there is no theoretical requirement of explicit decoding, as might typically occur in such tasks; any potential route or mode of activating the phonological form of the word simultaneously with its orthographic form would conceivably suffice (cf. [Share, 2008b](#)). Thus, in the present study we explore the possibility that an incidental exposure procedure in which no explicit reading is required may nevertheless result in orthographic learning, possibly via implicit phonological activation.

Factors beyond phonological processing may also mediate the effects of print exposure and contribute to orthographic learning ([Cunningham, Perry, Stanovich, & Share, 2002](#)), with visual processing being a primary candidate ([Bosse, Chaves, Largy, & Valdois, 2013](#); but see [Nation & Castles, 2017](#), for a critical discussion). Repeated reading has been found to increase reading fluency, an effect thought to be mediated primarily by orthographic learning ([Lemoine, Levy, & Hutchinson, 1993](#); [Levy, Nicholls, & Kohen, 1993](#); [Martens & De Jong, 2008](#)), consistent with visual episodic transfer between repeated encounters with specific words ([Levy, Di Persio, & Hollingshead, 1992](#)). [Bosse et al. \(2013\)](#) drew attention to “the simultaneous processing of all the orthographic units of a word” (p. 3) as a crucial visual attentional component of orthographic learning. Indeed, the number of letters that can be simultaneously recognized when rapidly presented is particularly associated with silent reading skill ([van den Boer, van Bergen, & de Jong, 2014](#)). Further support for the role of visual processing comes from studies showing that mixing uppercase and lowercase letters disrupts orthographic learning ([Martens & de Jong, 2006](#)).

Given that visual processes must carry the burden of identifying visual stimuli as letters toward the activation of orthographic representations, it stands to reason that more efficient visual processing may benefit or facilitate orthographic processing. Such effects may conceivably be independent from—or complementary to—the need for phonological activation, or they may interact with phonological activation efficiency to modulate orthographic learning. At any rate, an empirical question arises regarding the role—and the potential—of perceptual learning procedures to affect

orthographic learning and the extent to which they may do so in the course of regular reading exposure, in addition to whatever crucial (and indisputable) role is played by the activation of the phonological form. This neglected aspect of orthographic learning is the one we begin to address in the present study, focusing on bottom-up effects.

Fluent reading requires efficient word recognition, that is, automatic recognition of the letter strings that make up known words ([Wolf & Katzir-Cohen, 2001](#)). From this point of view, word recognition operates largely on the basis of orthographic knowledge ([Castles & Nation, 2006](#); [Nation & Castles, 2017](#)). That is, learning to read fluently amounts to acquiring accurate and stable orthographic patterns ([Martin-Chang, Ouellette, & Madden, 2014](#)) plus developing a set of efficient processes to deploy this knowledge over word sequences (cf. [Protopapas, Altani, & Georgiou, 2013](#); [Zoccolotti, De Luca, & Spinelli, 2015](#)). Moreover, spelling is but the expression of orthographic knowledge in writing, because accurate spelling is defined as the production of the appropriate letter strings corresponding to the intended words. Therefore orthographic knowledge forms the basis of spelling as well (consistent with strong learning transfer effects between reading and spelling; [Conrad, 2008](#)). And because spelling depends entirely on internal orthographic representations, lacking the benefit of external cues to help define or disambiguate words, spelling skill is considered a more stringent index of orthographic knowledge than reading efficiency ([Holmes, Malone, & Redenbach, 2008](#); [Shahar-Yames & Share, 2008](#)).

In addition to knowledge of how specific words are spelled, the term orthographic learning has also been applied to general knowledge about spelling patterns and constraints on letter use ([Apel, 2011](#)). This kind of knowledge is statistical in nature, rather than rule-based ([Pacton, Fayol, & Perruchet, 2005](#)) and seems to be acquired implicitly, through exposure to written language, very early on ([Cassar & Treiman, 1997](#); [Pacton, Perruchet, Fayol, & Cleeremans, 2001](#); [Pollo, Kessler, & Treiman, 2009](#); [Taylor, Plunkett, & Nation, 2011](#)). The statistical regularities of spelling patterns seem to be extracted on the basis of knowledge of individual words, as suggested by studies of the development of morphological spelling, that is, spelling of inflectional and derivational affixes ([Chliounaki & Bryant, 2007](#); [Pacton & Deacon, 2008](#)). These findings suggest that (a) strengthening of recurring spelling patterns may be more fruitfully approached via reinforcement of orthographic representations for particular words rather than by the teaching of abstract rules; and (b) implicit learning through exposure to words may be effective in strengthening statistical orthographic knowledge not only in beginner readers but in older children as well. Thus, an effective orthographic learning procedure emphasizing specific words seems likely to generalize to other words with common patterns, affecting orthographic representations more generally ([Tucker, Castles, Laroche, & Deacon, 2016](#)). To achieve this, we have adapted a well-known procedure from the perceptual learning literature, well-suited to incidental, visually mediated learning.

1.2. Task-irrelevant perceptual learning

Task-irrelevant perceptual learning (TIPL; [Seitz & Watanabe, 2009](#)) is the phenomenon whereby detection or discrimination of task-irrelevant stimuli improves when they are consistently presented at behaviorally relevant times ([Seitz & Watanabe, 2005](#)), such as simultaneous with task targets ([Seitz, Lefebvre, Watanabe, & Jolicoeur, 2005](#); [Seitz & Watanabe, 2003](#)) or rewards ([Seitz, Kim, & Watanabe, 2009](#)). This learning is attributed to the elicitation of nonspecific neuromodulatory signals, resulting from behaviorally relevant events, that interact with attentional mechanisms to select and reinforce neural activity that is correlated with

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