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Learning to read and spell: how we acquire word orthographic knowledge

Introduction

Nowadays, reading and spelling abilities are essential to integrate within literate societies like ours. Try to imagine how difficult it would be to travel, communicate or study without reading and spelling. This is why learning to read and spell is an essential objective of school education. However, even today, too many children leave school with poor reading and spelling abilities (1). Therefore, it seems crucial to fully understand the complex procedure of reading and spelling acquisition, in order to propose efficient teaching methods, to better help children with specific difficulties and in fine to decrease the academic failure and fight illiteracy. In this article, we focus on a specific part of this complex procedure, the fundamental acquisition of the orthographic knowledge of words which is in fact acquiring the knowledge of thousands of lexical forms.

Learning to read and spell words relies on the acquisition of at least two types of knowledge. First, children need to acquire decoding skills (i.e., to learn, and to learn how to use grapheme to phoneme correspondences) in order to be able to process and read newly encountered words, and also to generate phonologically plausible spelling when they write. The cognitive mechanisms by which children learn decoding skills have been extensively studied and described in the last decades (see 2 for a review).

However, becoming an expert reader and speller involves much more than just having efficient decoding skills. It requires acquiring the knowledge of thousands of word orthographic forms. This knowledge permits to instantaneously recognize words at a glance instead of sequentially decoding them, and consequently to read fluently and to put all the attention on meaning during reading. The knowledge of word orthographic forms also permits to spell words correctly. Word spelling first depends on the letter-sound code, which does not have a simple one to one correspondence in inconsistent orthographies such as English or French. For example in English, the phoneme /k/ can be spelled with c (cat), k (kiss) or ch (chord). Moreover, word spelling also depends on morphological rules and can contain orthographic particularities, which have various origins like etymology or foreign words. In this sense, an efficient orthographic knowledge involves the storage of thousands of specific word orthographic forms that is the knowledge of both identity and position of each letter in thousands of words (see 3 and 4 for two models of letter position coding distinct from letter identity coding into orthographic lexical memory).

In order to evaluate word orthographic knowledge, researchers and teachers can measure reading fluency or lexical decision speed. They can also test whether the reader recognizes specific word orthographic forms, using irregular word reading. However, to evaluate precise accuracy of word orthographic knowledge, they might prefer using a task of choice between several homophones (e.g., choose the right spelling between these two: take-taik) or spelling under dictation. In this case, they can analyze spelling errors and complete the quantitative measure with a qualitative analysis. For

example, they can spot which grapheme has not been memorized and distinguish letter identity errors from letter transposition errors.

Although the acquisition of word orthographic knowledge is a key step for becoming an expert reader and speller, its cognitive mechanisms, involved during implicit or explicit learning, remain largely underspecified and are presently a central issue in literacy research (5). Moreover, several types of knowledge can interact during this acquisition (e.g., knowledge of letter string frequencies and of the morphological structure of words) which also depends on linguistic factors or learning strategies. In this article, we only review current knowledge about the way we normally acquire most of our word orthographic knowledge: unintentional word orthographic acquisition via reading and spelling. We will focus specifically on the role of three essential cognitive variables: decoding skills, visual processing and handwriting.

The role of decoding skills

Orthographic acquisition first depends on language. Without language, only a small number of orthographic forms can be memorized after thousands of reinforced learning trials (see 6, for an experiment with baboons). The situation is clearly different when the learner can link an orthographic form with language. In this case, the acquisition of word orthographic knowledge depends on the establishment of connections between written and spoken forms of words (e.g., 7).

Reading by decoding could then be considered as a situation that favors these connections. During decoding, the reader processes the written form of the word and generates its spoken form sequentially (e.g., grapheme by grapheme or syllable by syllable). At the end of the word decoding process, both the spoken form and the written form of the word are available and the connection between the two can begin to be established. Thus, decoding acts as a self-teaching device enabling the decoder to develop his/her word orthographic knowledge necessary for skilled reading (i.e., the self-teaching hypothesis, 8; see 9 for an implementation of the self-teaching hypothesis in the dual route theoretical frame).

A lot of empirical studies have investigated word orthographic self-teaching during decoding. They all confirm that, from the second grade, knowledge of the orthographic form of a word never encountered before could be acquired only after having read this word a few times. Results on first graders are less homogeneous (e.g., 10), suggesting that the self-teaching mechanism could be less efficient when decoding skills are not automated yet. It also seems that word orthographic acquisition begins from the first decoding of a new word (11, 12) and strengthens during the following readings of the same item (13, 11). Interestingly, word orthographic acquisition during decoding seems equivalent whether the new word is presented in isolation or whether it is included in a short text (11), except for very irregular words (14). In this particular case, children can benefit from contextual support.

Therefore, it appears that decoding acquisition is not only the step leading to grapheme to phoneme mapping learning. Decoding is really the critical step of reading acquisition that permits the future acquisition of most word orthographic knowledge, via the autonomous reading of all newly encountered words. However, there is also evidence that decoding cannot be the only factor related to word orthographic learning. Nation et al. (11) showed that the relation between decoding and word orthographic learning did not hold at an item-by-item level of analysis. Sometimes, children

decode a word correctly but don't memorise its orthography at all. Sometimes, the word orthographic form is memorised despite the fact that the word has not been decoded correctly. Moreover, for the same level of decoding abilities, some children memorise word orthographic forms better than others (10, 15, 11). Thus, which other cognitive factor than decoding ability can influence word orthographic knowledge acquisition?

The role of visual processing

Since reading is the act of understanding a linguistic message from a visual information, visual factors may play a crucial role in successful word orthographic knowledge acquisition during reading. Several authors have already suggested that differences in visual processing might determine word orthographic self-teaching as a secondary source of variance (15, 8). This hypothesis is supported by recent theoretical and empirical data suggesting that word orthographic knowledge acquisition during reading involves specific visual word processing. More precisely, the ability to process simultaneously all the letters of a word might be a second key factor contributing to word orthographic learning.

For a long time, the theoretical models of visual processing during reading attributed a central role to visual attention (e.g., 16, 17). Most of the current models of adult reading hypothesise, more or less implicitly, that expert word reading requires the simultaneous processing of all the letters of the word read (e.g., 18, 19). The possibility to process all the letters of the word simultaneously, like an expert, or to shift to an analytic sequential processing, like a beginning reader, has even been implemented in a connectionist model of polysyllabic French word reading (20). In this model, the acquisition of a whole-word orthographic knowledge is possible only when all the letters of the word are visually processed simultaneously. When the visual processing system is not able to efficiently process the entire word orthographic sequence at a glance, the word orthographic knowledge cannot be acquired. Accordingly, although decoding is critical for the acquisition of orthographic knowledge, the ability to spread visual attention over the whole-word letter string could also be a crucial factor to word orthographic learning beyond the contribution of decoding skills (21).

In line with this theoretical hypothesis, poor simultaneous visual processing abilities in dyslexic children were found to account for the children's poor reading outcome independently of their phonological and decoding skills (22, 23). Bosse and Valdois (24) showed that simultaneous visual processing abilities of first, third and fifth graders contributed specifically to their performance in irregular word reading, which relies on word orthographic knowledge. The unique contribution of the simultaneous visual processing abilities to reading remained large and stable over grades for irregular words but decreased sharply from the first grade to later grades for both regular words and pseudo-words. This latter result suggested some specific influence of simultaneous visual processing on word orthographic knowledge acquisition.

However, these results were only correlational data that could not evidence a causal relationship between simultaneous visual processing and word orthographic knowledge acquisition. Moreover, the tasks usually used to estimate simultaneous visual processing involve letter processing and verbal report. Consequently, the causal status of a visual attention factor independent of a verbal factor in reading and spelling acquisition is still strongly debated (25-28) and clearly needs more investigation.

Longitudinal studies, training studies (see 29) and experimental studies are specifically suitable to test the causal link.

With this goal, Bosse, Chaves, Largy, and Valdois (30) directly manipulated the amount of letters simultaneously available during reading. Participants had to read new bisyllabic words and were later evaluated on their orthographic knowledge of these words. Word orthographic learning was compared between two learning by reading conditions. In one condition, all the letters of the new word could be processed simultaneously during the reading phase while in the other condition, only one syllable of the word was available at a time and the participant had to read sequentially. The results showed that word orthographic knowledge is acquired more easily when all the letters of the word are simultaneously available (see also 31 for similar results with another paradigm to disrupt letter string simultaneous processing).

To sum up, both theoretical models and available empirical data suggest that word orthographic knowledge, acquired implicitly during reading, might rely not only on decoding skills but also on the child's ability to simultaneously process the entire letter string of the word. When a child sees a written word he had never read before, he will memorise this new word orthographic form better if he can 1) decode the word correctly using its grapheme to phoneme correspondence knowledge and 2) visually process all the letters of this word simultaneously. Even if this causal relationship has to be confirmed by training and longitudinal studies, it seems plausible that the two main cognitive factors involved in implicit word orthographic acquisition during reading are decoding skills and visual processing skills.

The role of writing

Even if most of the word orthographic knowledge acquisition is supposed to be performed during reading, additional tasks can improve this acquisition. At school, the most frequent task used to enhance orthographic acquisition is handwriting. Benefits of handwriting on literacy acquisition have been described in several studies (e.g., 32, 33) but few studies investigated specifically the benefits of handwriting on word orthographic knowledge acquisition. Recently, two studies have confirmed superior word orthographic learning resulting from writing practice than from reading practice alone (34, 35). They found that word orthographic training was more efficient when children had to write the item they just read than when they had to think silently of the item they just read or when they had to reread the item again.

Because handwriting is a very complex cognitive task, it seems crucial to understand why it is beneficial to word orthographic acquisition. The first explanation is that writing involves more processing than reading, because it requires exhaustive letter-by-letter consideration and fully operational connections between sounds and letters (36). Moreover, when writing a word several times, the child must process each and every letter exhaustively at each production. On the contrary, when reading a word several times, the representation may be less than fully specified yet sufficient for word identification (37).

Another specific aspect of handwriting practice likely to enhance word orthographic acquisition concerns the motor-kinesthetic aspects of writing production. When they learn concomitantly to read and write, children associate each letter with highly specific writing movements and each word letter-string with specific grapho-motor patterns. Accordingly, grapho-motor patterns and visual

orthographic features may form a sensory-motor representation of orthographic knowledge in memory, in line with the embodied cognition theory (38). Behavioural and neuroimaging data have also demonstrated that writing movements are involved in letter memorization. For example, handwriting contributes more than typing to the visual recognition of isolated letters (39). Moreover, the visual presentation of a single letter activates the premotor regions involved in handwriting, even when the task does not require any motor response (e.g., 40). Such findings suggest a reactivation of motor knowledge during single letter visual processing. However, the contribution of handwriting on whole-word orthographic memorization, that is memorization of multi-letter strings, has not been clearly established yet.

In sum, two causal hypotheses are generally proposed to explain why writing practice improves word orthographic knowledge acquisition more than word reading practice alone. The first hypothesis is that writing involves more exhaustive letter-by-letter processing. The second is that writing provides the additional motor-kinesthetic information that contributes to the word representation in memory. In order to differentiate between these two causal hypotheses, we recently tested whether the writing practice advantage on lexical orthographic learning is mainly due to exhaustive letter-by-letter processing, or whether additional motor-kinesthetic information yields more efficient orthographic learning (41). For this purpose, word orthographic acquisition after a handwriting practice was compared with word orthographic acquisition after a spelling-aloud practice. Both practices involved exhaustive letter-by-letter processing and immediate recall, but only the spelling-by-hand practice provided additional motor-kinesthetic information. The results suggested that word orthography learning by handwriting was slightly more efficient than learning by spelling aloud. However, this hypothesis needs further researches to be confirmed.

In this study, we also confirmed the strong encoding-retrieval match effect: memory performance is enhanced if the type of task at encoding matches the type of task at retrieval (e.g., 42, 43). In the experiment, items learned by handwriting were spelled better when they had to be handwritten, and items learned by spelling aloud were spelled better when they had to be spelled aloud. As a consequence, it could be suggested that insofar as we need to frequently write rather than spell words aloud, the writing practice for learning word orthography is fully justified.

Summary and conclusion

This article focuses on specific word orthographic knowledge acquisition, which is a crucial part of reading and spelling acquisition because it is the main condition for reading and writing expertise. Even if the precise word orthographic knowledge acquisition mechanisms are far from being extensively described, we know that most of this acquisition is carried out implicitly during reading by decoding. As a consequence, being able to read by decoding seems to be the first condition to become an expert reader and speller. Secondly, both theoretical and empirical data suggest that it is also important to be able to visually process simultaneously all the letters of the word read, in order to better memorize its whole-word orthographic form. Thirdly, handwriting which is the task most frequently added to the reading task in order to memorize word orthographic forms, is beneficial for word orthographic knowledge memorization. These three points are important challenges for future theoretical models of reading and spelling acquisition.

These theoretical conclusions have also important practical consequences. They point out that learning decoding skills is the first crucial step in learning to read, because it will permit the beginning reader to decode more and more words in an autonomous way, and then to have more and more occasions to memorize whole-word orthographic forms. They suggest that as soon as the child is able to decode, it is important to favor rewarding autonomous reading situations, in order to let him/her encounter and decode a lot of words in different contexts. They also suggest that poor spellers could benefit from writing exercises which engage them to treat exhaustively all the letters of each word, and from reading exercises that enhance their ability to process simultaneously all the letters of written words, for example, progressive reading exercises using “flash card” or word rapid presentations on a computer screen. Finally, in order to detect as soon as possible children who might present reading and spelling difficulties in the future, it seems crucial to focus on early decoding difficulties (2), but also to pay more attention to both visual attention processing (44) and handwriting difficulties (45).

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