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Phonemic feature involvement in lexical access in grades 3 and 5: Evidence from visual and auditory lexical decision tasks

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ABSTRACT

Numerous studies have evidenced the involvement of the phonological code during visual word recognition not only in skilled adult readers but also in child readers. Moreover, in skilled adult readers, visual word processing has been shown to be sensitive to phonetic details such as phonemic features (e.g., manner of articulation, place of articulation, voicing and nasality in French) which are typically involved in phonological lexicon access during speech processing. In contrast, it is not known whether and when visual word recognition is affected by phonemic features during learning to read. The present study investigates this issue in third and fifth graders. A lexical decision task was performed in visual and auditory modalities. Targets were French words (e.g., *piano* [piano]) and pseudowords created from target words. Mismatching was on the first phoneme. There were one-feature phoneme mismatch pseudowords (e.g., *tiano*) and multiple-feature phoneme mismatch pseudowords (e.g., *liano*). The pseudowords were used as a marker of the sensitivity to phonemic features in phonological lexicon access. Phonemic feature effects were found in visual and auditory lexical decision tasks in both grades, indicating that phonological lexicon access involves phonemic features in print processing as in speech processing. In contrast, the absence of difference between both grades seems to indicate that this effect is independent of age or, more precisely, of phonological development and reading performance.

1. Introduction

The phonological code is known to play a critical role in lexical access during visual word recognition in skilled adult readers (for reviews, see Berent & Perfetti, 1995; Frost, 1998; Rastle & Brysbaert, 2006; Van Orden, Pennington, & Stone, 1990) and child readers (e.g., Booth, Perfetti, & MacWhinney, 1999; Goswami, Ziegler, Dalton, & Schneider, 2001; Grainger, Lété, Bertand, Dufau, & Ziegler, 2012; Johnston, Rugg, & Scott, 1988; Johnston & Thompson, 1989; Sauval, Casalis, & Perre, 2016; Ziegler, Bertrand, Lété, & Grainger, 2014). Furthermore, it has been shown in skilled adult readers that visual word recognition is sensitive to phonemic features (Lukatela, Eaton, Lee, & Turvey, 2001) that are typically involved in speech processing (Connine, Blasko, & Titone, 1993). On the other hand, it is not known whether the phonological code is involved at such a detailed level in visual word recognition in children. This is an important issue because it might show the development of the deep inter-connection between the written word and speech processing systems and the importance of creating close links between orthography and phonology during learning to read (Hatcher, Hulme, & Ellis, 1994). The present experiment attempted to provide evidence for the involvement of phonemic features in lexical access during reading development.

Numerous studies in skilled adult readers have shown that written word recognition involves activation of the phonological lexicon (Ferrand & Grainger, 1992, 1993, 2003; Grainger & Ferrand, 1996; Perfetti, Bell, & Delaney, 1988; Van Orden, 1987; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000; for a review see Berent & Perfetti, 1995; Frost, 1998; Rastle & Brysbaert, 2006). Recent data obtained in skilled adult readers suggest that visual word processing is affected by phonetic details that are typically used in spoken language processing such as vowel length, stress and phonemic features (Ashby, Sanders, & Kingston, 2009; Cooper, Cutler, & Wales, 2002; Lukatela et al., 2001; Lukatela, Eaton, Sabadini, & Turvey, 2004). Phonemic features characterize phonemes. For French consonantal phonemes, phonemic features are the manner of articulation, the place of articulation, voicing and nasality. Consonants are phonologically close when they share three phonemic features (e.g., /z/ and /s/ share the place and manner of articulation and nasality) and phonologically distant when they share fewer than three phonemic features (e.g., /v/ and /s/ share only the manner of articulation and nasality). In a masked priming

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experiment performed in skilled adult readers, Lukatela et al. (2001) found a phonemic feature effect: visual words were recognized faster when the visual masked prime was a pseudoword phonologically close to the target (e.g., ZEA-sea) than when it was a pseudoword phonologically distant from the target (e.g., VEA-sea). This indicates that the orthographic code automatically activates the phonological code at a level as fine as sub-phonemic units during visual word recognition. Lukatela et al. (2001) suggested that the visual word recognition system is deeply inter-connected with the spoken word recognition system in skilled adult readers.

As mentioned above, spoken word processing involves phonetic details such as vowel length, stress and phonemic features (Friedrich, Schild, & Röder, 2009, Soto-Faraco, Sebastián-Gallés, & Cutler, 2001, in adults; Gerken, Murphy, & Aslin, 1995; Schild, Röder, & Friedrich, 2011; Swingley, 2003, in children). Studies in skilled adult readers have investigated phonological lexicon activation by varying the degree of matching between the auditory item and the phonological lexical representation (e.g., Connine et al., 1993; Dumay et al., 2001; Friedrich, 2005; Friedrich, Kotz, Friederici, & Gunter, 2004; Slowiaczek, Nusbaum, & Pisoni, 1987; Soto-Faraco et al., 2001), especially by manipulating phonemic features (e.g., Andruski, Blumstein, & Burton, 1994; Cole, 1973; Connine, Titone, Deelman, & Blasko, 1997; Friedrich et al., 2009; Milberg, Blumstein, & Dworetzky, 1988; Schild, Röder, & Friedrich, 2012). In a priming experiment using pseudowords as primes, Connine et al. (1993) showed that the target NUMBER was recognized faster when the prime was a one-feature phoneme mismatch pseudoword (/ˈmʌmbə^r/) than when it was a multiple-feature phoneme mismatch pseudoword (/ˈkʌmbə^r/). This result supports the idea that lexical activation depends on the number of phonemic features shared between the spoken item and the lexical representation.

The bi-modal interactive-activation model (BIAM; e.g., Diependaele, Ziegler, & Grainger, 2010; Grainger & Ferrand, 1994; Grainger, Kiyonaga, & Holcomb, 2006; Grainger & Ziegler, 2011; based on the interactive-activation model of McClelland & Rumelhart, 1981) combines spoken and written input and processing in a single model. In the BIAM, the description of spoken language processing is based on the TRACE model of speech perception (McClelland & Elman, 1986), which is organized into three levels of processing: feature, phoneme and word. Lexical activation depends on the number of phonemes activated and their activation level, which depends on the number of phonemic features activated by speech (see note[1] for a detailed explanation). This means that the BIAM takes phonemic features in lexicon activation from speech into account. Regarding written language processing, a visual word stimulus first activates a set of visual features, which in turn activates the grapheme representations. A central interface between orthography and phonology (O ⇔ P) enables grapheme representations to be mapped onto their corresponding phoneme representations. Thus, a set of phoneme representations is activated and spreads activation to phonological lexical representations. Even if connections between phoneme and phonemic feature representations are present in the BIAM model, the authors did not report any involvement of phonemic features in phonological lexical activation during visual word processing. At the lexical level, connections between orthographic and phonological representations also influence the course of visual word recognition.

In children, the phonological code is known to be involved in word reading (e.g., Booth et al., 1999; Goswami et al., 2001; Grainger et al., 2012; Johnston et al., 1988; Johnston & Thompson, 1989; Sauval et al., 2016; Ziegler et al., 2014). In a lexical decision task, Grainger et al. (2012) showed that the phonological code was involved from first to fifth grade and in skilled adult readers. This involvement decreased as reading level increased. These results suggest that phonological mediation is essential at the beginning of learning to read, i.e. during the phonological recoding phase, and that its impact remains even when reliance on orthographic processing increases, namely when words are familiar and recognized automatically without recourse to phonological recoding (Booth et al., 1999; Sauval, Perre, & Casalis, 2017; Ziegler et al., 2014). In children, involvement of the phonological code during visual word recognition has always been studied at lexical or phonemic levels and, to our knowledge, phonological involvement at phonemic feature level has not yet been investigated (for a study in pre-reader children, see Rack, Hulme, Snowling, & Wightman, 1994). It is still not known whether phonemic features are activated during print processing and, if so, whether phonemic features are involved from the onset of visual word recognition or whether this occurs more with age and as relationships between orthography and phonology become deep and finely tuned (Lukatela et al., 2001). The aim of this study was to examine this issue in children, who mostly use word recognition to process reading, i.e. after the stage of phonological recoding. The present study therefore focused on two stages of learning to read: third and fifth grades.

We investigated this issue using a lexical decision task. This task has two advantages: (1) it does not require the spoken phonological code, unlike a naming task; and (2) it is not a simple binary choice such as deciding whether a stimulus is red or blue but involves different processes according to the type of items (words vs. pseudowords). In a lexical decision task, words are processed more accurately and faster than pseudowords. The "yes" decision ("it is a word") is a function of lexical activity (mainly dependent on word frequency) generated by the stimulus, whereas the "no" decision ("it is not a word") is determined by how much the pseudoword looks like a real word (e.g., Binder, Medler, Westbury, Liebenthal, & Buchanan, 2006; Rubenstein, Richter, & Kay, 1975; Stanners, Forbach, & Headley, 1971). The more the pseudoword resembles a real word, the greater the amount of lexical activity and the less the "no" answer is accurate (there are more errors) and quick (for models, see the diffusion model, Ratcliff, Thapar, Gomez, & McKoon, 2004; the Bayesian reader model, Norris, 2009; the multiple read-out model, Grainger & Jacobs, 1996; or the leaky competing accumulator model, Dufau, Grainger, & Ziegler, 2012). In our experiment, we focused on the "no" response it because reflects the amount of lexical activity generated by pseudowords.

We created two types of pseudowords by varying the number of phonemic features shared with the French target words, hereafter called basewords. The phonologically close pseudowords varied in only one phonemic feature (e.g., *tiano* from *piano* [piano]) whereas the phonologically distant pseudowords varied in multiple phonemic features (e.g., *liano* from *piano*). The pseudowords were used as a marker of the degree of precision with which the phonological lexicon is activated during visual word recognition. Our hypotheses were the following: (1) if phonemic features are involved in lexical access from visual stimuli (Lukatela et al., 2001), then a phonemic feature effect may be expected, i.e. it should be harder to reject the one-feature phoneme mismatch pseudoword (e.g., *tiano*) than the multiple-feature phoneme mismatch pseudoword (e.g., *liano*); and (2) if phonological code activation during visual word recognition becomes more precise with age and thus finer, then the phonemic feature effect should be stronger in fifth grade than in third grade. Additionally, an auditory lexical decision task using the same material was performed in order to ensure that children in both grades activated phonological lexical representations at a phonemic feature level of precision (Schild et al., 2011). In the auditory lexical decision task, we expected the same pattern of results in both grades, i.e. a lexical effect and a phonemic feature effect.

[1] The architecture of the TRACE model (McClelland & Elman, 1986) consists of a large number of units organized into three levels: feature, phoneme and word. Input is sent sequentially to the feature unit level in successive slices as the speech stream unfolds over time. The speech cue determines a pattern of activation over the feature units. Each activated feature activates all the phonemes including this feature. Given that phonemes receive activation from one or more features, the phoneme activation level is proportional to the input pattern from the feature level. Furthermore, phonemes send activation to all words including these phonemes. The word activation level depends on the number of phonemes activated and their activation level. Excitatory feedback is also sent from lexical to phoneme level and from phoneme to feature level.