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Coarse and fine N1 tuning for print in younger and older Chinese children: Orthography, phonology, or semantics driven?

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ABSTRACT

Visual expertise in distinguishing words from objects and word-like stimuli is a fundamental skill that is important for children to become proficient readers. This expertise can be indexed by the N1 component of ERPs at the neural level. However, the nature of N1 tuning for print is controversial in terms of onset of the latency, lateralization and the neural mechanism of the N1. This study aimed to investigate whether two groups of Chinese children could discriminate characters/character-like stimuli from visual controls (i.e., coarse N1 tuning) and distinguish characters from character-like stimuli (i.e., fine N1 tuning). We also explored the cognitive-linguistic correlates of N1 tuning. Seventeen children in the younger group (M=7.7 years) and 13 in the older group (M=9.4 years) were all required to finish a character decision task with character, pseudocharacter, noncharacter, and stroke combination conditions using ERP testing. Both the pseudocharacters and noncharacters were unpronounceable, and the main difference between the two conditions was in orthographic presentation (i.e., radical position). Children were also administered measures of reading fluency, reading accuracy, RAN, phonological skill and vocabulary knowledge. ERP results showed that a significantly larger N1 was observed in the characters, pseudocharacters, and noncharacters as compared to the stroke combinations in both groups. The N1 for characters and pseudocharacters was also significantly larger than that for noncharacters in both groups. Both coarse and fine N1s were larger for younger children than for older children, and the N1 was bilateral in younger children, but left lateralized in older children. Correlational analyses showed that the coarse N1 tuning of real characters versus visual controls was moderately correlated with reading fluency and accuracy but not RAN, phonology, or vocabulary. Taken together, our study suggests that both coarse and fine N1 tuning occurs in both younger and older children, when performing character decisions. Under such task demands, orthography, rather than phonology or semantics, seems to be the driver of coarse N1 tuning for print in Chinese children.

1. Introduction

The expertise to distinguish words from objects (e.g., symbols) and word-like stimuli (e.g., consonant strings) is a prerequisite for children to become proficient readers across scripts (Bentin et al., 1999; Brem et al., 2005; Cao et al., 2011; Cohen et al., 2000; Maurer and McCandliss, 2008; Maurer et al., 2008). A number of studies have shown that children who have received a certain amount of formal literacy training can discriminate words from objects such as lines or false fonts, which can be indexed by the N1 component at the neural level in event-related potential (ERP) research (defined as coarse N1 tuning for print) (Brem et al., 2005; Maurer and McCandliss, 2008; Maurer et al., 2005, 2011, 2008; Wong et al., 2005). The N1 is a negative-going ERP component peaking at around 200 ms after stimulus onset with localization

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over the left occipital-temporal cortex in skilled readers (Maurer and McCandliss, 2008; Michel et al., 2004; Rossion et al., 2002; Tarkiainen et al., 1999). However, understanding about the development of print tuning is limited (Zhao et al., 2014), and results regarding its topographic distribution are inconsistent across studies and scripts in children (e.g., Tong et al., 2016). Moreover, we know little about when children discriminate words from word-like stimuli such as pseudowords and nonwords at the neural level, which is defined as fine N1 tuning for print (Eberhard-Moscicka et al., 2015; Zhao et al., 2014). In particular, the nature of N1 tuning for print remains controversial (Eberhard-Moscicka et al., 2015; Maurer and McCandliss, 2008). This study aimed to investigate (1) whether two groups of Chinese children with mean ages of 7.7 and 9.4 years, respectively, would show both coarse and fine N1 tuning for Chinese print and (2) whether the N1 tuning for print would correlate with some of the cognitive-linguistic skills, including rapid automatized naming (RAN), phonological awareness, semantics skills, or reading fluency and accuracy, that underpin reading.

1.1. The coarse and fine N1 tuning for print

The coarse N1 tuning for print, referring to the N1 differences between word/word-like stimuli and visual controls such as false-fonts, develops very fast in children after their schooling, as found in different scripts (Cao et al., 2011; Maurer et al., 2005). The development of the coarse N1 tuning follows an inverted U shape with a large N1 for print at the initial stage of reading acquisition and decreases with age (Maurer et al., 2006). The typical N1 tuning for print localizes in the left temporal-occipital areas, but the degree of left-lateralization varies across studies (Tong et al., 2016). For example, German-speaking younger readers tend to show a bilateral distribution (Eberhard-Moscicka et al., 2015), but the N1 print tuning becomes more left-lateralized with further reading training (Maurer et al., 2006); it was found to be left-lateralized in children after grade 2 (Maurer et al., 2011). However, another study has shown that such tuning tends to be bilateral in older children (Araújo et al., 2012). Findings on the lateralization of the coarse N1 in Chinese children are also inconsistent. Cao and colleagues reported left lateralized coarse N1 tuning for Chinese in 7–year-old Mainland children (Cao et al., 2011). However, a recent study showed that the coarse N1 tuning for Chinese appeared to be bilateral in 7-8-year-old Hong Kong Chinese children (Tong et al., 2016).

The initial development of coarse N1 tuning for print is also unclear. In a longitudinal study, for example, Maurer and colleagues found that N1 coarse tuning was absent in German-speaking kindergarteners with a mean age of 6.47 years old, but a larger N1 for German words than symbol strings was shown in the same children only after they had received 1.5 years of schooling at the age of 8.26 years old (Maurer et al., 2006). Zhao et al. (2014), however, reported that German-speaking children around 7 years old with only .6 years of school training in literacy had showed a larger N1 for familiar German words as compared to symbol strings (Zhao et al., 2014). A larger N1 for words than false font strings in children with a mean age of 7.6 years old was also observed in a recent study (Eberhard-Moscicka et al., 2015), further suggesting that coarse tuning may occur earlier than has been reported in prior studies.

While there have been many studies on the coarse N1 tuning for print in children, only a few studies have been conducted to examine the fine N1 tuning for print, referring to the N1 differences between words and pseudowords and nonwords (Araújo et al., 2012; Bentin, 1999; Eberhard-Moscicka et al., 2015; Hauk et al., 2006; Zhao et al., 2014). Pseudowords are those words that are legal in orthographic and phonological structure in alphabetic languages. In contrast, nonwords are those words that are illegal in terms of orthography in a language. The differences across real words, pseudowords and nonwords on N1 could reflect the degree of orthographic processing in children. Findings on when the fine N1 tuning emerges and whether there is an N1 difference between words and pseudowords are also inconsistent across studies (Eberhard-Moscicka et al., 2015). Some studies have reported a detectable N1 difference between words and pseudowords in German-speaking second graders with a mean age of 8.26 years (Maurer et al., 2006). In contrast, two recent studies did not did not observe significant differences between words and pseudowords on N1 overall in 7-year-old German-speaking children (Eberhard-Moscicka et al., 2015; Zhao et al., 2014). However, a larger N1 was elicited by real words and pseudowords relative to consonant strings, suggesting that the fine N1 tuning between real words/pseudowords and consonant letter strings occurred in those 7-year-old German-speaking children (Zhao et al., 2014).

1.2. The nature of N1 tuning for print: orthography, phonology or semantics driven?

There are three hypotheses in explaining the underlying mechanism of the N1 tuning for print in the literature. The first hypothesis can be understood by making reference to the visual perceptual learning account (i.e., refers to the orthographic processing hypothesis in this study). This account proposes that N1 tuning is free from linguistic influences such as phonological information processing, and it emphasizes that the perceptual expertise for orthographic regularities causes the larger N1 for word and word-like stimuli than for visual controls (Bentin et al., 1999; Lin et al., 2011; Wong et al., 2005). For example, a larger N1 (i.e., N170) was evoked by single Roman letters, which do not contain any linguistic information, than pseudofonts in English-speaking adult readers (Wong et al., 2005).

In contrast, the second hypothesis, namely, the phonological mapping hypothesis, holds the view that N1 tuning reflects the top-down phonological information processing involved in letter-sound mapping in visual word reading (for a review, see Maurer and McCandliss, 2008). This hypothesis is driven by the connection between the topographic distributions of the N1 tuning effect and auditory processing. Specifically, the typical N1 tuning effect is left-lateralized and the brain areas associated with auditory processing including phonology are located in the left temporal-occipital regions (McCandliss and Noble, 2003; Price et al., 1997; Rumsey et al., 1997). Researchers thus infer that the left-lateralized N1 tuning might be caused by top-down phonological information involved in early visual word recognition (Maurer et al., 2003b). This hypothesis has been supported by a number of empirical studies (for a review, see Maurer and McCandliss, 2008). However, in a very recent study, Eberhard-Moscicka et al. (2015) found that coarse N1 tuning for print observed in German-speaking children with a mean age of 7.6 years old was not related to any phonological measures (i.e., phoneme deletion and pseudoword segmentation). In contrast, word reading fluency and vocabulary were the two important factors explaining the largest part of total variance in print tuning. In particular, vocabulary accounted for 7.8% of the variance in N1 print tuning beyond the contribution of other reading and cognitive-related factors. The authors argued that it should be the semantics rather than phonology that lead to the N1 tuning effect for print.

1.3. The present study

The above review shows the inconsistency of findings related to the onset of latency and lateralization of N1 tuning across studies and scripts, and the question of what the N1 reflects remains