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The neural correlates of rhyme awareness in preliterate and literate children

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HIGHLIGHTS

- Behavioral and electrophysiological responses were recorded while (pre)literate children made rhyme judgments of rhyming, overlapping and unrelated words.
- Behaviorally both groups had difficulty judging overlapping pairs as non-rhyming while overlapping and unrelated neural patterns were similar in literates.
- Preliterates show a different pattern indicating a developing phonological system.

ABSTRACT

Objective: Most rhyme awareness assessments do not encompass measures of the global similarity effect (i.e., children who are able to perform simple rhyme judgments get confused when presented with globally similar non-rhyming pairs). The present study examines the neural nature of this effect by studying the N450 rhyme effect.
Methods: Behavioral and electrophysiological responses of Dutch pre-literate kindergartners and literate second graders were recorded while they made rhyme judgments of word pairs in three conditions; phonologically rhyming (e.g., *wijn-pijn*), overlapping non-rhyming (e.g., *pen-pijn*) and unrelated non-rhyming pairs (e.g., *boom-pijn*).
Results: Behaviorally, both groups had difficulty judging overlapping but not rhyming and unrelated pairs. The neural data of second graders showed overlapping pairs were processed in a similar fashion as unrelated pairs; both showed a more negative deflection of the N450 component than rhyming items. Kindergartners did not show a typical N450 rhyme effect. However, some other interesting ERP differences were observed, indicating preliterates are sensitive to rhyme at a certain level.
Significance: Rhyme judgments of globally similar items rely on the same process as rhyme judgments of rhyming and unrelated items. Therefore, incorporating a globally similar condition in rhyme assessments may lead to a more in-depth measure of early phonological awareness skills.

1. Introduction

Sensitivity to rhyme develops early in life. Infant studies have shown that nine-month-olds already respond to changes in rhyme pattern or even smaller changes within the rhyme constituent of a word (Hayes et al., 2000, 2009). Nonetheless, the ability to *consciously* attend to phonological information does not develop until the age of three and generally starts with an awareness of rhyme (Chard and Dickson, 1999; Vloedgraven and Verhoeven, 2007). Therefore, rhyming tasks are often incorporated in screening measures for the detection of early language and literacy problems in both research and practice. However, these rhyme awareness assessment are often fairly simple in nature and do not encompass more demanding conditions that tap into the more developed levels of rhyme awareness. For example, although it is clear that most children can rhyme prior to the start of formal education, there is evidence that they have not yet fully mastered this skill. Behavioral studies have shown that kindergartners can easily state that *bell* and *ball* rhyme, due to the global phonological similarities between these two words (Carroll and Snowling, 2001; Wagensveld et al., 2012). In contrast, first grade children seem to be less sensitive to this so-called *global similarity effect* (Cardoso-Martins, 1994), which is possibly a result of their reading

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experience which is known to lead to more developed phonological awareness (Adams, 1990; Blachmann, 2000; Snowling and Hulme, 2005). Although there are event-related potential (ERP) studies that have examined rhyme processing in young children, the global similarity effect has not been studied in young children by means of this method. We will therefore investigate the neural correlates that play a role in rhyme processing and the processing of other types of phonological overlap in preliterate kindergartners and reading second grade children.

1.1. Rhyme processing in the brain

Neural correlates of rhyme have first been studied in adults. ERP research has shown that the human brain responds differently to rhyming and non-rhyming words. This effect was first described by Rugg (1984a,b) who found that, in a visual rhyme judgment task, non-rhyming words elicited a more negative deflection in the ERP waveform than rhyming words. For example, the target word *cause*, which was preceded by the non-rhyming prime word *clams*, led to a more negative deflection than the similar target word *pause*, which was preceded by the rhyming prime word *claws*. In addition to these results with words, the effect was also observed when pseudoword stimuli were used. The rhyme effect was maximal around 450 ms after the onset of the target and was found mainly around the midline and over the right hemisphere. The observed component that was involved in the effect was originally described as a separate rhyme-sensitive ERP component and named *N450 component* after its peak-latency. The N450 component has also been described as a more general sensitivity to phonological mismatch of the N400 component (Perrin and Garcia-Larrea, 2003, Praamstra et al., 1994, Radeau et al., 1998); the ERP component that is involved in semantic processing (Kutas and Hillyard, 1980, 1984). Therefore, the component has also been labeled the *phonological N400*. However, in the present study, we will refer to the component using the original N450 terminology to prevent misunderstandings.

Since the initial publications by Rugg, various studies have examined the properties of the N450 component and the N450 rhyme effect. From these studies, it has become clear that the N450 rhyme effect can be elicited by a wide range of stimuli varying from relatively simple items, such as single letters (Coch et al., 2008b), to more complex multi-syllabic pseudowords (Dumay et al., 2001). Praamstra and Stegeman (1993) found that the component is not solely elicited by visual stimuli. In a phonological priming study, they showed that auditory stimuli also influenced the N450 amplitude, even when the prime and target (pseudo)-words were spoken by a different speaker. Furthermore, a study exploring the role of visual features showed that the N450 component did not differ for letters that were presented in lowercase or uppercase (Coch et al., 2008a). In conclusion, the N450 component can be considered as a merely phonological measure, since the component was not influenced by physical orthographic features.

Measuring EEG has several advantages. First, the method provides insight into the neural processes that take place immediately after presentation of the stimulus and can therefore display processing differences that precede any physical responses that are measured in behavioral research. Another advantage is that the method is non-invasive, unlike other neuro-imaging techniques (e.g., functional magnetic resonance imaging), which makes it a very suitable method to use when examining children. A series of children studies performed by Coch and colleagues have addressed the developmental pattern of the N450 rhyme effect. In a rhyming study using visual stimuli they examined children (who could already read) and adults in age groups ranging from 7 to 23 years old (Grossi et al., 2001). They found that the N450 rhyme effect is already present at age 7 and does not change during further development; the distribution and amplitude of the effect were stable across the age groups. The same results were obtained in a study using auditory stimuli (Coch et al., 2002) and more recent in a letter-rhyme task (Coch et al., 2011). Although the distribution and amplitude of the N450 rhyme effect are rather stable, the onset is more variable. In a more recent ERP study Coch et al. (2005) investigated rhyme effects in 6-, 7- and 8-year-old reading children with low and high phonological awareness skills. Although no amplitude differences were found, the onset of the N450 rhyme effect appeared to be later for the children with low phonological awareness scores. Also, studies examining participants with reading difficulties have found that poor readers showed decreased N450 rhyme effects as compared to typical readers (Ackerman et al., 1994; Desroches et al., 2012; McPherson et al., 1998), indicating that the N450 rhyme effect is influenced by different levels of reading.

Although the N450 component was first observed using rhyming stimuli, the effect does not seem to be restricted to rhyme overlap at the end of a word. Modulations of the N450 have also been found when non-rhyming stimuli were contrasted with alliterating stimuli (e.g., *beeld-beest*) in adults (Praamstra et al., 1994), in typically developing preliterate and literate and even dyslexic children (Bonte and Blomert, 2004a,b). Furthermore, the N450 rhyme effect can also be elicited by word-final overlap that is larger or smaller than the rime constituent of a word. Dumay et al. (2001) examined phonological priming using bi-syllabic French words and pseudowords. In this study the targets were preceded by primes that overlapped in syllable (e.g., *lu<u>rage</u> – ti<u>rage</u>*), rime (e.g., *lub<u>age</u>-tir<u>age</u>*) or coda (e.g., *luso<u>ge</u> – tira<u>ge</u>*). The responses to these experimental conditions were compared to responses to a control condition which consisted of unrelated prime-target pairs (e.g., *lusole-tirage*). The ERP results showed that all three experimental conditions led to a reduction of the N450 amplitude. Interestingly, the amount of phonological overlap had a graded effect on the amplitude of the N450. The amplitude reduction was largest for syllable overlap, intermediate for rime overlap and smallest for coda overlap as compared to the unrelated control condition. Thus, the N450 appears to be sensitive to the degree of phonological overlap, which makes it a suitable instrument to explore differences in ERP between rhyme and other types of phonological overlap.

1.2. Rhyme processing in children: the global similarity effect

Behavioral research has shown that kindergarten children who can make rhyme judgments on simple word pairs such as *wall-ball* are easily confused when they are presented with words that contain another type of phonological overlap such as *bell-ball*. These phonological distracters are often judged incorrectly as rhyming pairs (Cardoso-Martins, 1994; Carroll and Snowling, 2001). This so-called *global similarity effect* has been explained as a result of the ill-defined phonological representations in a young child's mental lexicon (Carroll and Snowling, 2001; De Cara and Goswami, 2003; Walley et al., 2003). In a recent behavioral study we attempted to shed light on the role of lexical representations in rhyme processing (Wagensveld et al., 2012). Dutch children were presented with a rhyme judgment task containing rhyming pairs (e.g., *g<u>ek</u>-b<u>ek</u>*, "*strange-beak*"), overlapping pairs that shared the same onset and coda consonant (e.g., *<u>b</u>a<u>k</u>-<u>b</u>e<u>k</u>*, "*box-beak*") and unrelated pairs (e.g., *sop-bek, "lather-beak*"). To examine the role of lexical representations in the judgment of these word pairs the children were also presented with a series of Dutch pseudoword pairs (e.g., *b<u>aam</u>-d<u>aam</u>*, *<u>d</u>ie<u>m</u>-<u>d</u>aa<u>m</u>*, *not-daam*). We found that preliterate children were slower and made more errors for the pseudowords which indicated that they could not solely rely on the mental lexicon for their pseudoword judgments. Interestingly, we observed an equally large global similarity effect in word and