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A neurocognitive perspective on rhyme awareness: The N450 rhyme effect

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ABSTRACT

Rhyme processing is reflected in the electrophysiological signals of the brain as a negative deflection for non-rhyming as compared to rhyming stimuli around 450 ms after stimulus onset. Studies have shown that this N450 component is not solely sensitive to rhyme but also responds to other types of phonological overlap. In the present study, we examined whether the N450 component can be used to gain insight into the global similarity effect, indicating that rhyme judgment skills decrease when participants are presented with word pairs that share a phonological overlap but do not rhyme (e.g., bell–ball). We presented 20 adults with auditory rhyming, globally similar overlapping and unrelated word pairs. In addition to measuring behavioral responses by means of a yes/no button press, we also took EEG measures. The behavioral data showed a clear global similarity effect; participants judged overlapping pairs more slowly than unrelated pairs. However, the neural outcomes did not provide evidence that the N450 effect responds differentially to globally similar and unrelated word pairs, suggesting that globally similar and dissimilar non-rhyming pairs are processed in a similar fashion at the stage of early lexical access.

1. Introduction

Around three decades ago, Rugg (1984b) designed an event-related potential (ERP) experiment to examine hemispheric lateralization effects of phonological processing by using rhyming and non-rhyming stimuli. Although it was not intended, they were the first to observe and describe the neural correlate of rhyme processing in the human brain as a negative deflection of the ERP waveform for non-rhyming as compared to rhyming words around 450 ms after target onset, which maximizes at mid-line and right hemisphere electrodes. A subsequent study (Rugg, 1984a) showed that similar ERP patterns can be obtained by comparing rhyming and non-rhyming pseudowords. In this study, the component was first labeled as N450. These seminal observations by Rugg and colleagues have led to an array of studies

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examining the properties of the N450 component and the N450 rhyme effect (i.e., the larger N450 amplitude for non-rhyming as compared to rhyming stimuli). From these studies, it has become clear that the N450 component and the N450 rhyme effect are rather salient. However, it is not clear whether the N450 rhyme effect only applies to rhyme or also to other forms of phonological overlap. This question will be tackled in the present article.

1.1. *The N450 rhyme effect*

The N450 component and the N450 rhyme effect can be distinguished well in adults and can also be observed in children from an early age. Seven-year-olds already display an adult-like pattern (Coch et al., 2005,2002; Grossi et al., 2001). Furthermore, they are observed with stimuli from different modalities; both visual (Rugg, 1984a) and auditory rhyming stimuli (Praamstra and Stegeman, 1993) elicit an N450 component and display an N450 rhyme effect when rhyming and non-rhyming stimuli are compared. Both the component and the effect are also observed when using relatively simple stimuli such as isolated graphemes (Coch et al., 2008a) and more complex multi-syllabic pseudoword stimuli (Dumay et al., 2001). It has also been found that the N450 component and rhyme effect are not sensitive to physical orthographic features as was evidenced in studies that found comparable N450 effects when stimuli were presented in different letter cases (Coch et al., 2008b; Rugg and Barrett, 1987). Following their outcomes, (Coch et al., 2008b argued that the N450 component and subsequently the rhyme effect most likely reflects a purely phonological measure.

However, even though the component was named as N450 and the effect is referred to as the N450 rhyme effect, studies have shown that the component is not solely sensitive to rhyme overlap. Praamstra et al. (1994), for example, also found that the component responds to alliterating stimuli, such as *beeld–beest* (*statue–beast*). This finding has led to the hypothesis that the N450 component not only reflects rhyme processing but can be seen as a general sensitivity to phonological overlap (Perrin and Garcia-Larrea, 2003; Praamstra et al., 1994; Radeau et al., 1998). Following this rationale, the component was used by Dumay et al. (2001) to explore word-final overlap of segments that were smaller or larger than the often-examined rhyme unit. In their study, they presented French adult participants with a lexical decision task containing prime-target pairs that overlapped in syllable (e.g., *lurage–tirage*), rhyme (e.g., *lubage–tirage*), final phoneme (e.g., *lusoge–tirage*) or were phonologically unrelated (e.g., *lusole–tirage*). The ERP data showed that the amplitude of the N450 component of the three overlapping conditions was smaller than the amplitude of the N450 component of the unrelated condition. Furthermore, the amplitude difference was smallest for pairs that overlapped only in final phoneme, intermediate for pairs with rhyme overlap and largest for pairs with syllable overlap suggesting that the amplitude of the N450 component increases with the amount of phonological overlap in (pseudo)words.

1.2. *The global similarity effect*

Judging rhyme in word pairs is generally described as an analytical process during which the rhyme unit of a prime word is segmented from its onset, then stored in phonological memory and then compared to the segmented rhyme unit of the target word (Bryant and Bradley, 1985; Bryant et al., 1990; Kirtley et al., 1989; Ziegler and Goswami, 2005). An alternative view states that rhyme processing relies on a more global comparison of the similarities in the whole word unit. Evidence for this hypothesis comes from behavioral studies which showed that phonological overlap in word pairs that do not rhyme (e.g., *bell–ball*) causes interference, leading to slower response times and more incorrect rhyme judgments. This so-called global similarity effect has first been observed in two phonological classification studies by Treiman and Baron (1981); Treiman and Breaux (1982). In the first study (Treiman and Baron (1981)), pre-literate children and adult skilled readers were presented with syllable triads (e.g., *bis–dIz–bun*). Within each triad, one syllable pair shared a common initial phoneme (e.g., *bis–bun*) and one pair was overall more similar containing three similar sounding phoneme pairs (e.g., in *bis and dIz, 'b' and 'd','i' and 'I', and 's'and 'z' sound similar*). Participants were asked to classify the triads under free classification instructions, meaning that participants could put together whichever pair of syllables they found appropriate. When children were asked to select the two syllables that they thought belonged together, they were more likely to choose the overall similar pair. Adult participants tended to select the common phoneme pair more often. A follow-up study using a training paradigm confirmed the finding that while adult processing relies primarily on common phoneme relations, pre-literate children base their judgment on global similarity relations between lexical items (Treiman and Breaux, 1982). A more recent study confirmed the finding that the use of phonemic information in classification becomes more common with age (Carroll and Myers, 2010).

Global similarity relations have also been shown to influence rhyme judgments in studies with Portuguese, English and Dutch speaking preliterate children (Cardoso-Martins, 1994; Carroll and Snowling, 2001; Wagensveld et al., in press). These studies showed that preliterate children, who could easily judge rhyming pairs (e.g., *wall–ball*) and unrelated non-rhyming pairs (e.g., *dog–ball*), had great difficulty deciding whether two phonologically similar non-rhyming items (e.g., *bell–ball*) rhymed or not. As in the phonological classification studies, it has also been suggested that global similarity relations have less influence on rhyme judgments when age increases. Cardoso-Martins (1994) found that 83% of first graders were able to perform a rhyme task containing phonological distracters well, as opposed to only 43% of kindergarten and 10% of preschool children. The findings of these rhyme studies and the classification experiments suggest that the global similarity effect becomes less prominent after the start of formal education.

In sum, the previously described behavioral studies have made clear that rhyme performance decreases when participants are presented with globally similar non-rhyming items. So far, this global similarity effect has been interpreted as a developmental effect that arises due to the ill-defined nature of the underlying holistic lexical representations earlier in childhood (Carroll and Snowling, 2001).

1.3. The present study

At present, it is unclear that which processes lead to the slower and more often incorrect judgment of globally similar word pairs. One possibility is that these items are initially processed in a similar fashion as rhyming pairs due to the phonological overlap and at a later stage recognized as non-rhyming, delaying the response times. On the other hand, it is also possible that globally similar items are processed similar to phonologically unrelated non-rhyming items and decision times take longer because some type of reanalysis is undertaken after the phonological overlap is recognized. A third option is that the globally similar items are being processed in a unique manner that does not reflect the processing of either rhyming or phonologically unrelated non-rhyming word pairs.

So far, behavioral studies have not been able to make a clear distinction between the processing of rhyming and phonologically related and unrelated non-rhyming word pairs. In the present study, we examined whether the N450 component presented a suitable tool to shed light on the processes underlying rhyme judgments in general and the processing of globally similar non-rhyming pairs more specifically. Our aim was to examine whether the global similarity effect is reflected by a differential response of the N450 component to globally similar items as compared to rhyming and unrelated items. Participants were presented with a rhyme judgment task. They were asked to judge rhyming (e.g., *kaas–haas*, 'cheese–hare'), phonologically overlapping (e.g., *huis–haas*, 'house–hare') and phonologically unrelated non-rhyming (e.g., *dun–haas*, 'thin–hare') word pairs as quickly as possible by means of a 'yes–no' response. Button press responses provided us with behavioral information of the global similarity effect while EEG measures were taken to examine the neural correlates of rhyme and global similarity processing. To find an answer to our research question, we explored to what extent a difference in the N450 component can be observed for phonologically similar non-rhyming pairs as compared to phonologically unrelated non-rhyming pairs on top of an N450 rhyme effect.

2. Results

2.1. Behavioral outcomes

Fig. 1 displays the mean response times of the rhyme judgment task. Analysis of the response latency data revealed a main effect of condition ($F(2,38)=4.805$, $p=0.020$, $\eta^2_p=0.202$). There was a global similarity effect, as the overlap condition was judged slower than both the rhyme condition ($t(19)=-2.550$, $p=0.020$, $d=0.320$) and the unrelated condition ($t(19)=-2.104$, $p=0.049$, $d=0.200$). The response times of the rhyming and unrelated condition did not differ significantly ($t(19)=-1.325$, $p=0.201$, $d=0.120$).

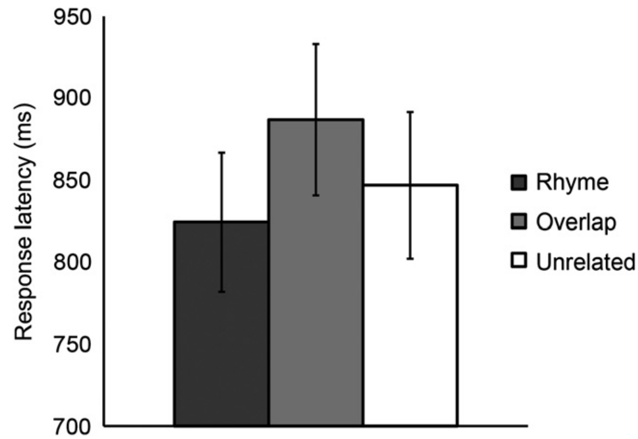

Fig. 1 – Mean response latencies in milliseconds of the rhyming, overlapping and unrelated condition of the rhyme judgment task. The bars represent the standard error of the mean.

2.2. Electrophysiological results

Fig. 2 displays the grand average waveforms for the rhyming overlapping and unrelated condition. The grand averages were time-locked to the onset of the target. As is evident from Fig. 2, there was an N450 rhyme effect for the rhyming compared to the non-rhyming conditions between 250 and 500 ms. The omnibus ANOVA showed that there was an interaction between anteriority (anterior, posterior) and condition (rhyme, overlap, unrelated; $F(2,38)=4.846$, $p=0.016$, $\eta^2_p=0.203$). To examine this interaction, two ANOVAs were performed for anterior and posterior electrodes separately. There was no main effect of Condition at anterior locations but the effect was significant at posterior locations ($F(2,38)=5.278$, $p=0.017$, $\eta^2_p=0.217$). This latter effect was further examined by means of paired sample *t*-tests which showed that at posterior electrodes, the N450 component for the rhyming condition was smaller than for the overlapping ($t(19)=2.384$, $p=0.028$, $d=0.720$) and unrelated condition ($t(19)=2.855$, $p=0.010$, $d=0.880$). No differences could be observed between the overlap and unrelated condition ($t(19)=0.622$, $p=0.541$, $d=0.190$). Thus, the N450 component was sensitive to rhyme in word pairs but did not respond to pairs that shared a phonological overlap but did not rhyme. The neural data, in other words, did not show a global similarity effect.

3. Discussion

The present study has combined behavioral and neural measures to shed light on the influence of global similarity relations on adult rhyme judgments. So far, the global similarity effect had only been observed in children and has been explained as a developmental effect that was the result of ill-defined lexical representations (Carroll and Snowling, 2001). The behavioral data of the present study provided evidence that a global similarity effect is present in adult skilled readers: participants responded more slowly to the

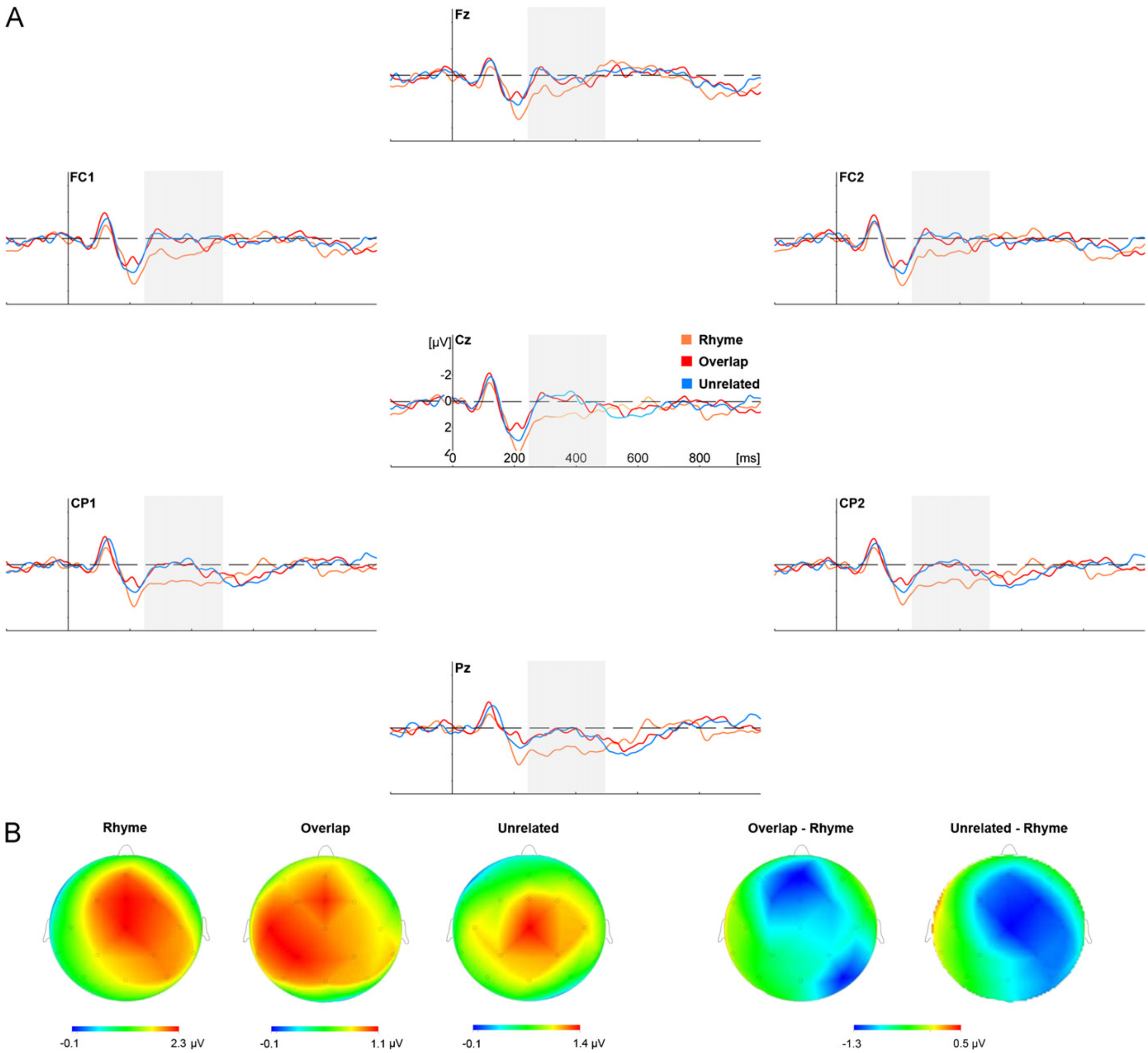

Fig. 2 – (A) Grand average event-related potentials for the three conditions from 7 scalp sites. The event-related potentials were time-locked to the onset of the target word. Please note that negativity is plotted upward. The N450 effect was found for the rhyming condition compared to both the overlap and the unrelated condition from 250 to 500 ms at posterior electrodes. (B) Topographical maps of the mean amplitudes in the 250–500 ms time window for the three phonological conditions and the two rhyme vs. non-rhyme difference waveforms. Difference waveforms were created by subtracting the ERP of the rhyming condition from the ERP of the overlapping and unrelated condition, respectively. Please note that the scales of the maps differ per condition.

globally similar overlapping items than to the rhyming or unrelated items. This finding suggests that the global similarity effect is a more general effect and not a purely developmental pattern that arises as a result of ill-specified lexical representations in a child's lexicon. This outcome makes clear that the global similarity effect measures in children cannot be seen as an indication of their (dis)ability to make analytical rhyme judgments.

Although the behavioral data clearly showed the global similarity effect, the neural data presented a slightly different outcome. A clear N450 rhyme effect was evidenced; the N450 component showed a negative deflection for non-rhyming as compared to rhyming word pairs. The effect was mainly observed at posterior electrodes between 250 and 500 ms after the onset of the target making it consistent with previous observations (Coch et al., 2005; Dumay et al., 2001; Praamstra and Stegeman, 1993; Rugg, 1984b). Surprisingly, we could not find evidence for a differential response of the N450 component to the two non-rhyming conditions. The phonologically similar and the phonologically unrelated word pairs elicited a comparable N450 component, suggesting that in this rhyme judgment experiment the N450 component responds differently to rhyme than to other types of phonological overlap.

As has been argued in the introduction, the slower behavioral responses to globally similar items could reflect a delayed form of rhyme processing at the level of early lexical access, i.e., rhyming, overlapping and unrelated word pairs are judged in a similar fashion which is delayed in the overlapping condition. However, the slower response times could also be the result of a delay in the response process, i.e.. at the level of early lexical access the pairs are processed similarly but the delay arises at a later time point when the actual response is being prepared. The behavioral data itself could not distinguish between these two possibilities since this mainly provides post-lexical information. However, the electrophysiological measures could provide more insight in this matter monitoring the rhyme judgment process at the level of lexical access. The response of the N450 component indicates that at the early stage of lexical access the participants process the overlapping non-rhyming pairs in a similar fashion as the unrelated non-rhyming pairs. The non-rhyming conditions only differed in response time indicating that the longer response times of the overlapping condition as compared to the unrelated condition are the result of a delay at a post-lexical stage. These findings once more stress the importance of combining behavioral and neural methods in order to get more detailed information of processes related to rhyme awareness.

It is important to note that the finding that the brain processes globally similar items in the same manner as unrelated items during early lexical access is only partly in line with previous studies examining adult participants. Convergent evidence comes from a study with visual stimuli which showed that an N450 effect could only be observed when participants judged the presented words on the basis of phonological rhyme and not when they were asked to focus on orthographic similarities (Kramer and Donchin, 1987). However, in a study measuring responses to alliterating stimuli it was found that the N450 component is sensitive to word-onset overlap (Praamstra et al., 1994). Another study which examined three types of word-final overlap found a graded response pattern of the N450 component was evidenced (Dumay et al., 2001). A plausible explanation for this discrepancy in observations may lie in the differences in task instruction. It has been shown that the robustness of the N450 effect is sensitive to the type of task that is used (Perrin and Garcia-Larrea, 2003). Whereas an effect was present when participants performed a rhyme judgment task, the N450 rhyme effect could no longer be observed when participants passively listened to rhyming stimuli. In the studies described above (Dumay et al., 2001; Praamstra et al., 1994), which demonstrated an N450 rhyme effect to phonological overlap besides rhyme overlap, participants were asked to make lexicality judgments whereas the adults in the present study made specific rhyme judgments. It can thus be assumed that the focus on this specific phonological structure leads to the rhyme-specific response pattern of the N450 component.

This explanation is also in line with theories on the processes that underlie the N450 rhyme effect. In the seminal studies by Rugg (1984a), it was argued that during the rhyme task prime words activate word candidates that could possibly form a rhyming match. As a result, the non-rhyming targets that did not belong to these activated rhyme candidates elicited a larger N450. Following this rationale, the task instruction may influence the type of word candidates that are activated. If participants were asked to judge stimuli on the basis of rhyme overlap, primes should activate all rhyming candidates. Therefore, it is possible that in the present study word candidates that share other types of overlap are not activated by the prime word and thus elicit an N450 component that is comparable to the N450 component that is elicited by unrelated words.

Although more research is necessary on the nature of the N450 rhyme effect to make strong claims about the influences of task instruction and specificity to rhyme overlap, some considerations can be made. In one of his original papers Rugg (1984a) suggested that the N450 component might be closely related to the N400 component, which was originally described as a component that is sensitive to semantic incongruences (Kutas and Hillyard, 1980, 1984). Since these seminal studies by Kutas and colleagues, research has shown that the N400 is not only sensitive to meaning violations but can also respond to changes in word form (e.g., Holcomb and Grainger, 2006). The ERP effect observed in the present study could therefore also be interpreted as an N400 that is modulated by phonological mismatches, a possibility that has also been addressed in other papers that have examined the N450 rhyme component (Perrin and Garcia-Larrea, 2003; Praamstra et al., 1994; Radeau et al., 1998).

A related point to consider concerns the relatively early onset, around 250 ms, of the observed ERP rhyme effect. The present ERP effect resembles the N450 rhyme effect in distribution and general waveform pattern. However, due to this earlier onset, the effect can also be related to other components that have been described in a time-window preceding the N400/N450 component. Rugg (1984a) described a negative component prior to the N450 that was not sensitive to rhyme information but was sensitive to phonological overlap. Relating our results to this finding is difficult since the ERP effect observed in the present study was only responding to rhyme not just phonological overlap despite the earlier onset. Friedrich et al. (2004) have observed a component at a similar latency (P350) which was described as an index of phonological (mis)match between a prime and target. Again, the present ERP effect was observed in roughly the same time-window but as opposed to the left-lateralized P350 observed in the Friedrich study the present effect had a posterior distribution. All these ERP components (at least partially) seem to reflect a form-based incongruency between either the stimulus itself, or the expectation and the actual-occurring stimulus. Finally, the present data seemed to show a differential pattern for the globally similar condition as compared to the two other conditions at a very early time point, around 200 ms. One might speculate, that this effect would be related to the Mismatch Negativity (MMN) which is elicited when a stimulus is unexpected or different from previously presented stimuli (Naatanen et al., 1978). However, this effect was not significant in the present study, and further research would be needed to shed more light on this issue.

To conclude, to our knowledge, this study was the first to examine the neural correlates of the global similarity effect in adult rhyme judgments. From the present study, it can be concluded that adult rhyme judgment becomes more difficult when participants are asked to judge non-rhyming word pairs with phonological overlap. Behavioral outcomes suggest that this process is delayed for the globally similar non-rhyming items. Neural examination, however, showed that globally similar and dissimilar non-rhyming pairs are processed in a similar fashion at the stage of early lexical access. Although we did not find differential ERP effects for the two non-rhyming conditions it would be worthwhile to examine whether the global similarity effect is reflected by the same neural pattern in children and adults at risk for dyslexia. Rhyme awareness is one of the earliest from of phonological awareness (Adams, 1990; Chard and Dickson, 1999; Vloedgraven and Verhoeven, 2007), which is known to be an important prerequisite of learning to read (e.g., Blachmann, 2000). Developing a neural measure of rhyme processing skills, which encompasses information on global similarity processing, may result in a more optimized assessment of rhyme processing skills and possibly the advancement of literacy skills.

4. Experimental procedure

4.1. *Participants*

Twenty right-handed participants (17 female; average age: 21;9, SD 2;11) with Dutch as their native language participated in an electroencephalogram (EEG) study which was approved by the local ethics committee. All participants had normal hearing and (corrected to) normal sight and none had a known history of neurological problems. Each participant signed an informed consent form and was paid for participation.

4.2. *Stimuli*

Stimuli consisted of 36 monosyllabic CVC Dutch target words (e.g., *haas*, 'hare') that were each paired with a rhyming prime word (e.g., *kaas*, 'cheese'), a phonologically overlapping prime word (e.g., *huis*, 'house') and an unrelated prime word (e.g., *dun*, 'thin'). This resulted in a total of 108 pairs, of which 36 rhymed and 72 were non-rhyming. To balance the rhyme/non-rhyme ratio, 36 rhyming filler pairs were created that were not included in the data analysis. Stimulus examples can be found in Table 1. Prime-target pairs were assigned to three lists so that each target only occurred once in a list. Each list was presented during one experimental block, resulting in three blocks of which the order was counterbalanced over participants. So, in total each participant was presented with 108 experimental and 36 filler pairs.

All stimuli were digitally recorded at 44.1 kHz (stereo) on a Dell D610 latitude laptop in a sound attenuated room. The words were spoken by a female speaker into a Sennheiser ME62 (Wedemark, Germany) microphone. Recorded stimuli were carefully edited for precise onset and offset using a speech waveform editor (Praat, version 4.5.12). Mean duration of the words were 538 ms (SD 89) for rhyming primes, 529 ms (SD 99) for overlapping primes, 533 ms (SD 88) for unrelated primes and 522 ms (SD 87) for targets.

4.3. *Procedure*

Participants were tested in a sound-attenuated, electrically shielded room. They sat in front of a computer screen while prime-target pairs were presented to them over Sennheiser HD 433 headphones (Wedemark, Germany) at a comfortable listening level of 65 dB. Participants were instructed to respond to the pairs as quickly as possible by indicating with a button-press whether the pairs rhymed or not. Response hands were counterbalanced over participants. The start of each trial was indicated with the presentation of a white fixation cross for 950 ms on a black computer screen. Fifty ms later, a prime word was presented over de headphones which was followed by a target word after 1200 ms. Participants then had 3800 ms to respond, leading to a total trial duration of 6000 ms.

4.4. *EEG recordings*

EEG was recorded from 28 active electrodes using the Acticap system with Ag/AgCL electrodes (Brain Products, Gilching, Germany). Electrodes were mounted in an elastic cap, each referenced to the left mastoid. Electrodes were located at four midline sites (Fz, FCz, Cz and Pz) and 24 lateral sites (Fp1/Fp2, F7/8, F3/4, FC5/6, FC1/2, C3/4, CP5/6, CP1/2, P7/8, P3/4, T7/8, O1/2). Recordings from Fp1 and an electrode placed beneath the left eye were used to monitor vertical eye movement whereas horizontal eye movement was monitored via a bipolar montage with electrodes at the outer canthi of the left and right eye. Recordings were re-referenced offline to average mastoids. Signals were pre-amplified at the scalp and all impedances were kept below 20 kΩ for all channels, which is a standard setting for active electrodes. Recordings were amplified using a BrainAmp DC amplifier system (Brain Products, Gilching, Germany) and digitized online at a sampling rate of 500 Hz using a bandpass filter of 0.016–200 Hz. The EEG and EOG were recorded and digitized using the

Table 1 – Examples of the Dutch stimuli that were used in the rhyme judgment experiment. English translations are in parentheses.

Rhyming pairs			Overlapping pairs			Unrelated pairs		
kaas (*cheese*)	–	haas (*hare*)	huis (*house*)	–	haas (*hare*)	dun (*thin*)	–	haas (*hare*)
weg (*road*)	–	heg (*hedge*)	hoog (*high*)	–	heg (*hedge*)	sop (*lather*)	–	heg (*hedge*)
zout (*salt*)	–	hout (*wood*)	heet (*hot*)	–	hout (*wood*)	rem (*brake*)	–	hout (*wood*)
nies (*sneeze*)	–	kies (*tooth*)	kus (*kiss*)	–	kies (*tooth*)	map (*folder*)	–	kies (*tooth*)

Brain Vision Recorder software (Version 1.03, Brain Products, Gilching, Germany).

4.5. Behavioral data analyses

Response times[2] were measured from the onset of the target and were examined by performing repeated measures analysis of variance (ANOVA) with phonological condition (rhyme, overlap, unrelated) as a within subject factor. Significant main effects were further investigated by conducting t-tests on the following planned comparisons; rhyme vs. overlap, overlap vs. unrelated, rhyme vs. unrelated.

4.6. EEG data Analyses

EEG data were analyzed off-line using the Brain Vision Analyzer Software package (Version 1.05.0005, Brain Products, Gilching, Germany). The data were rereferenced to average mastoids, corrected for ocular motion (Gratton et al., 1983) and digitally filtered between 1 and 30 Hz. Data were averaged over an epoch of 1200 ms after the onset of target. Participants made only few errors (1.25%, SD 1.21). Only trials with correct responses were included in the analysis. On these segments a baseline correction of −150–0 was carried out, after which all segments with amplitudes below −75 μV and above 75 μV were automatically rejected leaving on average 34.75 (SD 1.25) trials in the rhyming condition, 35.20 (SD 1.58) in the overlap and 35.60 (SD0.94) in the unrelated condition per participant. These segments were averaged per condition, per participant and per electrode site.

The N450 rhyme effect was examined by means of omnibus repeated measures analyses of variance (ANOVAs) which were performed on the mean amplitude in the 250–500 ms time window. There were three within-subject factors: condition (rhyme, overlap, unrelated), hemisphere (left, right) and anteriority (anterior, posterior). Electrodes were assigned to cluster in the following way: left anterior (F7, F3, FC5, FC1, VB), right anterior (F8, F4, FC6, FC2, Fp2), left posterior (C3, CP1, CP5, P7, P3, O1) and right posterior (C4, CP2, CP6, P8, P4, O2). Interactions between anteriority and condition were further explored by performing two separate 3×12 ANOVAs, the one with conditions rhyme, overlap, unrelated and (anterior) electrodes VB, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FCz, FC2, FC6 and the other with conditions rhyme, overlap, unrelated and (posterior) electrodes C3, Cz, C4, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, O1, O2. GreenhouseGeisser correction for violation of sphericity assumption was applied when appropriate (Greenhouse and Geisser, 1959) and significant interactions with Condition were further examined by means of paired sample *t*-tests.

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[2] Mean accuracy scores were as can be expected in adults at ceiling level, and were therefore not further analyzed.

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