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Effect of maturation on suprasegmental speech processing in full- and preterm infants: A mismatch negativity study

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ABSTRACT

Infants born prematurely are at higher risk for later linguistic deficits present in delayed or atypical processing of phonetic and prosodic information. In order to be able to specify the nature of this atypical development, it is important to investigate the role of early experience in language perception. According to the concept of Gonzalez-Gomez and Nazzi (2012) there is a special intrauterine sensitivity to the prosodic features of languages that should have a special role in language acquisition. Therefore, we may also assume that pre- and full-term infants having months difference in intrauterine experience show different maturation patterns of processing prosodic and phonetic information present at word level. The aim of our study was to investigate the effect of these differences on word stress pattern vs. phoneme information processing.

Two age groups of infants (6 and 10 month-olds) were included in our study. 21 of 46 of the total of infants investigated were prematurely born with low birth weight.

We used the mismatch negativity (MMN) event related brain potential (ERP) component, a widely used electrophysiological correlate of acoustic change detection, for testing the assumed developmental changes of phoneme and word stress discrimination. In a passive oddball paradigm we used a word as standard, a pseudo-word as phoneme deviant, and an illegally uttered word as stress deviant.

Our results showed no differences in MMN responses in the phoneme deviant condition between the groups, meaning a relatively intact maturation of phoneme processing of preterm infants as compared to their contemporaries. However, the mismatch responses measured in the stress condition revealed significant between-group differences. These results strengthen the view that the total length of intrauterine experience influences the time of emergence of prosodic processing.

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1. Introduction

The last decade of infant studies showed how well the early discrimination abilities of acoustic input could predict the mature linguistic skills during language acquisition (Benasich & Tallal, 2002; Kuhl & Rivera-Gaxiola, 2008). It seems that understanding verbal utterances needs a well-developed processing of crucial information present in the speech signal at pre-lexical level. The infants' ability to use phonetic and prosodic information is one of the many factors in service of detecting words in the speech flow.

Experiments testing infants' early speech processing abilities show that they are able to discriminate between different phoneme categories (Dehaene-Lambertz & Dehaene, 1994). This ability is based on the emerging categorical perception, which means that while setting category boundaries the acoustic variants of one category contribute to the same percept relying on invariant features (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). As Dehaene-Lambertz and Pena (2001) claim this automatic and fast *perceptual normalization process* which is simultaneous with the acoustic feature processing of speech stimuli is present from birth on.

As it is well known from the first behavioral studies on word stress processing, infants are sensitive to the prosodic cues present in spoken utterances as well. Nazzi, Bertoncini, and Mehler (1998) demonstrated that newborns can differentiate between two languages based on their rhythmic properties. According to the *native language acquisition hypothesis* this general ability, similarly to phoneme discrimination, becomes language specific due to experience with one's native language around the 5th month of age (Nazzi, Jusczyk, & Johnson, 2000).

Emphasizing the role of early prosodic processing the concept of *prosodic bootstrapping* published by Nazzi and Ramus (2003) claims that infants show an exquisite sensitivity to language-general rhythmic properties present at sentence level and this helps detecting language specific word forms already at the second half of the first year of life. Moreover, it seems that words stress information is one of those important prosodic cues that contribute to the identification of word boundaries. This information may have a special role in languages where word stress is highly regular (as in Hungarian), or have a high percentage of stress regular words formed by a large set of bisyllabic words of similar stress pattern (as in English), contributing to biased processing of the specific pattern (trochaic unit: stressed syllable followed by an unstressed one). As the experimental results of Jusczyk, Houston, and Newsome (1999) revealed more than a decade ago, American babies of 7.5 months showed an exquisite sensitivity to the predominant trochaic stress pattern in English called as *trochaic bias*. However, a decade later, results of a cross-linguistic study (Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009) revealed an earlier emergence of this bias in German infants as compared to French ones.

The first electrophysiological studies on infants' automatic detection of trochaic pattern revealed discriminative abilities below the age of 6 months as well. Weber, Hahne, Friedrich, and Friederici (2004) and Friedrich, Herold, and Friederici (2009) found that German infants of 5 months could well discriminate words of different stress patterns, showing a positive mismatch response to deviants with stress on the first syllable contrasted with standards with stress on the second syllable (Weber et al., 2004), as well as for deviants with stress on the second syllable contrasted with standards of first syllable stress (Friedrich et al., 2009).

Friederici, Friedrich, and Christophe (2007) demonstrated in a cross-linguistic study that in German and French infants a language-specific word stress pattern detection was present as early as the 4th month of age. These electrophysiological data supported the behavioral results of Nazzi, Iakimova, Bertoncini, Frédonie, and Alcantara, (2006) and recently of Nazzi, Mersad, Sundara, Iakimova, and Polka (2013) who proposed that in case of European French-learning infants the rhythmic unit of French (the syllable) was used for segmenting continuous speech, a pattern assumed to have a similar role as the rhythmic unit of English (i.e. the trochaic stress unit) English infants rely on.

The primary focus of our present study was to shed light on the maturational and developmental factors of word stress processing as compared to phonetic information. Our question was when and how infants are able to use phoneme and stress information in order to discriminate different forms of the same word.

The secondary focus of this study was to compare the linguistic capabilities of premature and full term infants in order to better understand the importance of intra- vs. extra-uterine development and to shed light on the origin of common preschool language deficits of premature infants.

A recent study revealed an interesting phenomenon with respect to the possible role of early experience. As Gonzalez-Gomez and Nazzi (2012) suggest *the intrauterine experience favors processing prosody* over the other attributes of speech. As the two authors argue the uterus works as a low pass filter resulting in attenuated higher frequencies and allowing fetuses to process prosodic information (Griffiths, Brown, Gerhardt, Abrams, & Morris, 1994). Gonzalez-Gomez and Nazzi (2012) argue that even the in-utero vowel discrimination could be explained by suggesting that fetuses react to the stimuli on the basis of prosodic properties (cf. Lecanuet, Graniere-Deferre, Jacquet, and DeCasper (2000) who claim that differences in the structure of formants of the vowels make some syllables louder than the others causing the perceptual differences). Mampe, Friederici, Christophe, and Wermke (2009) found different cry patterns in case of French and German newborns according to their native-language prosody, which also demonstrate the special intrauterine sensitivity to prosodic features of languages.

For testing the role of intrauterine experiences on early perceptual abilities Gonzalez-Gomez and Nazzi (2012) tested if healthy preterm infants showed developmental lag in discrimination of consonant sequences. Their results revealed that preterm infants behaved according to their chronological age. These results are in concordance with the results of Pena, Werker, and Dehaene-Lambertz (2012) who did not find differences in phoneme discrimination between preterm and full-term infants. This result was also confirmed by Mahmoudzadeh et al. (2013) who, by using NIRS (near infrared spectroscopy), found further