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Research Report

Reduced stress pattern discrimination in 5-month-olds as a marker of risk for later language impairment: Neurophysiologial evidence

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Abstract

The study at hand investigates prosodic abilities of infants as early predictors of Specific Language Impairment (SLI), which is commonly diagnosed at a later age. The study is based on the hypothesis that the prosodic abilities of infants at risk for SLI are less elaborated than those of controls due to less efficient processing of the relevant acoustic cues. One of the most critical prosodic cues for word segmentation is stress pattern. In German as well as in English, the most frequent stress pattern of bisyllabics is the trochee, in which stress is placed on the first syllable. Using a passive oddball design, German 5-month-olds were examined with respect to their ability to discriminate different stress patterns of bisyllabics. Infants were grouped retrospectively based on their production performance at the ages of 12 and 24 months. In contrast to matched controls, infants with very low word production displayed event-related brain potentials with a significantly reduced amplitude of the discrimination response, i.e. a Mismatch Negativity (MMN), to the trochaic stress pattern. This amplitude difference indicates impaired prosodic processing of word stress during early development and may thus be taken as an early marker of risk for SLI.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Infant; Event-related potential (ERP); Specific Language Impairment (SLI); Mismatch Negativity (MMN); Prosody; Lexicon

1. Introduction

The electrophysiological Mismatch Negativity (MMN) component has been successfully used to investigate auditory processing in adults and infants. It can be elicited in a passive oddball design by presenting subjects with a block of identical stimuli (standards) occasionally replaced by acoustically deviant stimuli (deviants). The MMN is interpreted to reflect the pre-cognitive detection of a deviance in the auditory input from information established in sensory auditory memory. Its morphology is considered to provide a neurophysiological correlate of discrimination accuracy ([19], for a review, see [37]). In adults, the MMN peak usually occurs at a latency of 100–200 ms after change onset with a fronto-central distribution. In infants, the mismatch response might occur as a negativity similar to the adult MMN [3,27,29]. Yet, a positive discrimination response starting around 300 ms after change onset is also frequently reported in very young subjects [7,10,28,39]. Some authors proposed the latter positivity to be a genuine infant discrimination response reflecting certain aspects of brain maturation [52]. Others suggested the positive deflection results from preponderant slow wave activity masking the genuine MMN in infants [35]. This hypothesis is supported by the fact that using a highpass filter during ERP analysis of infant data has a pronounced effect on the discernibility of the infant MMN [56]. Still, it seems very likely that functional aspects are associated with the slow wave positive discrimination response seen in infants. For example, it was proposed that the positivity might reflect a change in bottom–up categorization rather than a top–down change detection as assumed for the MMN ([11] but see also

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[32]). Thus, in contrast to the MMN, the significance of the positive infant discrimination response is still under investigation (for comprehensive discussions, see [11,35,52]).

Crucially, the amplitude of the MMN is sensitive to the accuracy of the discrimination process for auditory stimuli itself. Moreover, the component can be elicited irrespective of the attentional and/or motoric abilities of subjects. These factors make it a useful tool in investigating clinical populations of all age groups [37].

The MMN has been successfully used to explore auditory processing of speech and non-speech stimuli in subjects at and not at risk for language problems. For example, electrophysiological evidence pointing to impaired discrimination abilities, i.e. reduced MMN amplitude for different speech contrasts, was shown for learning disabled children, children with language problems as well as for infants at risk for dyslexia [23,26,29,53]. In infants, the component is well established for (segmental) phonological processing of simple Consonant–Vowel (CV), complex VCV and CVCV stimuli [27–29]. These studies have investigated infant processing of phoneme duration, as temporal changes in the speech signal often provide important cues for phoneme recognition. Note that sensitivity to consonant duration increment and decrement embedded in complex speech sounds was reported for Finnish-learning newborns and 6-month-olds [27,29]. Yet, when Finnish newborns were presented with consonant duration decrement exceeding 160 ms, no MMN was observed [27]. A similar effect was reported when German 2-month-olds were presented with decrement of vowel duration [11].

In German, vowel duration is an important aspect of phonological processing on the segmental level. Similar to Finnish, vowel length contrasts cue semantic changes in the German language. Yet, in German, vowel length is also a crucial aspect of suprasegmental phonology, namely, syllable stress [54]. Suprasegmental information in stress timed languages like German or English, in turn, is considered to be important for segmenting the incoming speech stream. The adult language system was demonstrated to be sensitive to the systematical suprasegmental information contained in bisyllabics. Note that in English as well as in German the most frequent stress pattern in bisyllabics is the trochee, i.e. about 90% of CVCV items bare stress on the initial syllable [4,5,58]. In fact, English adults are very likely to consider a strong syllable as the onset of a new lexical word [4,6]. Thus, sensitivity to the most frequent native language stress pattern might also serve as a cue for word segmentation in infants learning English or German ('prosodic bootstrapping') [55]. In fact, results of previous behavioral research in 6- to 9-month-old German and English learning infants suggest a stable preference for the canonical native language prosodic pattern of two syllable content words, i.e. the trochee [20]. Moreover, infants in the older age group actually use stress pattern of bisyllabics for word segmentation [21]. This finding is generally referred to as the 'trochaic bias' [34]. In order to explore the development of the trochaic bias in German infants younger than 6 months, an MMN study was conducted [56]. In this study, German learning infants were presented with trochaic (stress on the first syllable) as well as with iambic (stress on the second syllable) bisyllabics. Irrespective of gender, it was demonstrated that the trochaic bias is already present at the age of 5 months, i.e. infants discriminated a trochaic item presented among iambic items but not vice versa.

On a mere perceptual level, it might be argued that aspects of saliency and position might account for this result. In general, onsets of auditory stimuli constitute particularly salient transients and are, furthermore, behaviorally relevant. In fact, first position syllables and first position complex tones have a certain processing advantage in terms of latency and amplitude of the MMN in adults [45]. Thus, a trochaic item starting with a long vowel syllable is more salient than an iambic one starting with a short vowel and can therefore be discriminated more easily by 5-month-old German infants (cf. [11,27]). Yet, the enhancement of the MMN for the trochaic item in German 5-month-olds might also relate to the existence of language-specific long term memory traces for the canonical stress pattern of the target language. In order to further clarify this question, a cross-linguistic study should be conducted. Furthermore, the question is still open as to whether infants at risk for Specific Language Impairment (SLI), i.e. infants who display low word production scores later in life, also display a trochaic bias at the age of 5 months.

According to the International Classification of Diseases [22], the diagnostic criteria for Specific Language Disorders (SLI) are specified as follows: language skills are below the 2 standard deviations cut-off point and they are at least one standard deviation below nonverbal IQ. Furthermore, there are no neurological, sensory or physical impairments that directly affect the use of spoken language nor is there a pervasive developmental disorder. Typically, males are more vulnerable than females [22,24,49].

With respect to the etiology of SLI, evidence in favor of a strong genetic component has been gathered [31,51]. However, behavioral measures can also indicate the at risk status for language problems in children. In fact, a strong correlation with onset of language production ('late talkers') and SLI has already been reported in several longitudinal behavioral studies [16,42–44,46,50,57]. It was demonstrated that about 70% of 'late talkers', i.e. children who produced less than 50 words at age 2 years, exhibit persisting phonological and syntactic deficits at 4 years of age. As pre-schoolers, late talkers show reduced MLU (Mean Length of Utterance) when compared to normal controls. An influential hypothesis concerning the correlation between word knowledge and language development states that language development in late talkers cannot be triggered due to reduced word knowledge at the critical developmental timepoint, i.e. around 2 years of age [2,30].