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Review article

Behavioral assessment of language brain processing in the first year of life

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ABSTRACT

An up-to-date review of the behavioral assessments of language development in the first year of life is reported. After recalling the anatomical bases of the early development of the auditory system, the different stages of language development during the first year of life are considered: discrimination, transition and perception. The different kinds of behavioral assessment during the course of the first year are then described by stressing their indications and limitations.

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1. Introduction

Human newborns are extraordinarily competent in the world of sounds and speech. They are able to cortically process acoustic features of language: rhythm,[1,2] stress and prosody,[3] voice timber,[4] speech[5–7] or native language.[8] On the contrary, vocal production appears extremely poor. Such apparent physiological asymmetry might depend on different levels of maturation.

The first sign indicating the ability to discriminate between the spectro-temporal features of sounds is demonstrated by neurophysiology: an electrophysiological response to changes of auditory inputs (deviant stimulus) after a repetitive stimulation with the same sound (standard stimulus) is revealed as a modification of the evoked potential, called mismatch negativity (MMN). MMN can be recordable even without attention (which makes possible the assessment in the neonate), and testify the ability of discrimination and recognition memory, capturing the first manifestations of cognition at birth.

However, a number of other techniques are used to assess speech perception skills in infants during the first year of life, including those based on psychophysical responses (changes in gross movements or sucking; neuro-vegetative reflexes) or on intentional motor behavior.

2. Anatomical and physiological bases of early auditory development

There is an evident correlation between the maturation of acoustic cerebral pathways and the development of auditory function. I refer to the review of Eggermont & Moore[9] for a detailed analysis of the anatomical and physiological development of auditory cerebral structures, while I summarize here the main features of this development during the third trimester of gestation and the first year of life.

During this period two stages of the auditory function maturation can be distinguished. The first one refers to the ability to discriminate, i.e. to recognize the differences between simple sounds or any speech phonemes. The second one refers to the ability to perceive, i.e. to recognize speech structure up to link the stimulus to its meaning. Discriminative abilities of acoustic stimuli are already present in the last trimester of gestation at a time when only brain stem and cortical marginal layers seem to have reached the early steps of maturation.

At that time there was the emergence and initial growth from the cochlear nerve to thalami of axonal neuro-filaments (first apparent in histochemical studies at about the 16th week of gestational life), followed by myelination visible by 27–29 weeks of fetal life, with increasing dendritic arborization and synapse formation. All that corresponds to the function of one subsystem underlying discrimination, responsible for the first analysis of stimulus features.

The second important subsystem expressing the parallel cortical maturation essentially consists of the temporary organization of the marginal layer This layer is mainly made of intrinsic transitory neurons, Cajal–Retzius (CR) cells whose main role is attracting migrating neurons to form cortical layers, and of cell processes consisting of axons and dendrites, in particular coming from the peripheral pathways through the reticular ascendant system (RAS). Brain stem with its peripheral afferents and the marginal layer are thus the anatomical substrates for the discrimination processing in this first period of life.

The second stage of auditory function starts at the beginning of the second semester of life and consists of the anatomical maturation of the cortex and its connections. Axonal neuro-filaments and myelination progressively involve auditory radiation, while cortex lamination is achieved. At this stage, the role of marginal layer is changing, going through the apoptosis of CR cells and the development of new transcortical connections. New connections with medial geniculate body will eventually substitute RAS. Maturing cortex thus becomes the substrate of perception. Cortical maturation is obviously dependent on sensory inputs as demonstrated by the negative effects of hearing loss and conversely by the positive consequences of deprivation correction by early cochlear implants.

3. Pre-cognitive abilities

In the very first months of life the reception of the auditory stimulus is mediated by several abilities usually considered as pre-cognitive because of the absence of an operational awareness. Information processing model gives a useful frame to explain the first steps of development through the individuation of individual basal abilities including auditory function.[10]

There are several tools based on the information processing model to asses cognitive competence of young infants.[11] Similarly to MMN, they generally assess the ability to discriminate a novel stimulus from an old one that has left a memory trace. Among these tests, the Fagan test of infant intelligence (FTII)[12] has shown its good predictive ability as to subsequent cognitive development,[13] definitely higher than that of traditional developmental scales.[14]

There is an increasing body of literature investigating the role of pre-cognitive abilities on language development.[15–19] Some basic functions were particularly studied to predict later capacity of language development: visual recognition memory, speed of information processing, attention, and representation ability.

Visual recognition memory is based on the child's preference for novel stimuli using the paradigm of comparison between two paired stimuli,[20] and is expressed by a score of novelty given by the percentage of time spent by infants in looking at the novel stimulus in relation to the total time spent in looking at both stimuli (familiar and new).

Stimulus familiarity has foundation so in the phenomenon of habituation, expressing the progressive loss of interest for repeated stimuli which leave a memory trace. As a result, the new interest of the infant observed when the stimulus changes (dishabituation), can be seen as a measure of discrimination ability.

A better visual recognition memory in the first months of life correlates with better understanding of language in the following months,[21] and better ability of expression (lexicon and morpho-syntactic rules) in the following years.[19,22]

The speed of information processing in infants is tested as a measure of response time in a paradigm of "violation of

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