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Perception of Dynamic Social and Non-social Stimuli in Preterm and Full-term Children: Neurocognitive Correlates in Early Childhood

Dmitriy Chegodaev, Polina Pavlova, and Nadezhda V. Pavlova

Ural Federal University named after the first President of Russia B. N. Yeltsin, Yekaterinburg, Russia

Abstract

Preterm birth is the leading cause of newborn deaths in almost all countries around the world. Whilst survivors encounter severe motor, cognitive and behavioral impairments during infancy or later in their lives, the studies of the recent years have demonstrated that the social development serving a basis for learning and cognition of the environment in human infants can be severely affected even in normally developing preterm born children (gestational age < 37 weeks). The current article presents a discussion on the behavioral as well as the neuroimaging aspects of the social maturation in preterm and full-term children, depicting complexity of the impairments and focusing on the involved brain structures. Further, authors perform the design of the longitudinal study of social and non-social perception in early childhood, implemented on the base of the Laboratory for Brain and Neurocognitive Development (Ural Federal University).

Keywords: prematurity, social development, early childhood, neurocognitive correlates

Corresponding Author:
Dmitriy Chegodaev
neuromediator@mail.ru

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1. Introduction

According to the World Health Organization report a world-wide rate of preterm birth is around 15 million babies per year with a prevalence of 7.4% in Russia [1]. Though perinatal and neonatal care services as well as rehabilitation methods improved in the last decades, most of the preterm children interfere motor, cognitive and socio-emotional impairments [2].

Although scientists face challenges in establishing infant studies and lack of appropriate methods, recently accumulated data on the significance of the development within the first year of life [3] and considerable role of social interaction in this process forced them to turn the minds to the aspects of social development of preterm infants.

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Moreover, it has been shown that either born late and moderately preterm babies are at a high risk for altered cognitive and socio-emotional development at preschool and later age [2, 4, 5] along with the born extremely preterm children [6, 7].

1.1. Behavioral studies

Rather wide range of research groups succeed to assess different features of behavioral aspects of alternations in social development of preterm children.

Thus, in a behavioral cohort study by Cheong et al (2017) moderate or late preterm (MLPT, n = 198) compared to born-in-term (n = 183) children (using Bayley Scales of Infant Development-Third Edition, Infant Toddler Social Emotional Assessment) exhibited delays in cognitive, language and motor development, as well as poorer social-emotional outcomes at 2-year-old age [2].

Meanwhile, review of the behavioral aspects of social cognition by Zmyj et al. (2017) demonstrates the restriction of observations and questionnaires as methods of behavioral assessment in high-risk children: caregivers tend to overestimate behavioral traits and emotional expressions of their children. Thus, there is a high chance of obtaining false positive results of impaired behavioral development in these groups. At the same time, the difficulties in interactions of preterm with peers and others are based on the deficits in motor and cognitive development, as well as on the strategies of parent–child interactions, experienced during the first year of life [8, 9].

More objective, likewise demanding more resources from children eye-tracking studies allow remotely follow the gaze of a person and assess its features (e.g., direction, attractiveness of area of interest, time of fixation, saccade velocity). Using this technique in the experiments, Japanese group demonstrated less preference of human social dynamic tasks (human figure to objects), lower level of gaze-following (ability to redirect visual attention according to the gaze of the person) and first gaze shifts both at 6 and 12 preterm infants (corrected month age), compared to the full-term once [10]. Likewise, Telford et al (2016) obtained data, demonstrating differences in social orienting of preterm and full-term infants at the age of 7 month, such as scanning face (attention to the eyes or mouth), duration of fixation at face in pop-out task and attention, paid to the social scene. Accordingly, proportional looking time was consistently lower in preterms, while no between-group significant differences in raw looking time were found [11].

Eye-tracking studies demonstrate weakness of the components of social function in preterm infants, such as atypical social attention, gaze-following, but incapable to discriminate the level of the social functional system impairment (e.g., sensory or executive).

1.2. Neuroimaging studies

MRI study, conducted by an Australian group on quite a large cohort of full-term and term-equivalent preterm born infants (n = 249) have demonstrated that MLPT babies tend to have smaller brain size, delays in gyral maturation and myelination. Authors suggest the disruption of expected within 2 last months in utero brain grows trajectory, as presumable mechanism leading to the severe long-term outcomes [12]. Either the changes in cortex development suggested to be another reason for alternations in the development of preterm children, including social maturation [13, 14].

Current studies succeed to evaluate either separate features of infants' and children social development, or complex multimodal real-environment interactions. Thus, functional near infra-red spectroscopy (fNIRS) with an advantage of high signal-to-noise ratio along with the features of infants' skull allow us to obtain data of high spatial resolution on brain activation during real-life social interaction (for review see [15]). Although, it have to be mentioned, that fNIRS has lower accuracy in establishing the connection of activity and anatomical structures, compared with EEG [15]. Interestingly, data on the fNIRS studies in healthy preterm children is rather scarce [16]. Though, technique is widely applied for assessment of social development in healthy children and children at high-risk for ASD [17, 18].

Series of studies, assessing features of attention in full-term and corrected to the gestational age extremely preterm infants, report between-group neurophysiological differences in theta synchronization as soon as at the age of 4-to-5-month. Thus, the amplitude of theta rhythm was reduced in preterm infants in occipital and parietal electrode sites during presence of the object for attention, while within the phase of anticipatory attention results demonstrated localized reduction of theta synchronization in the lower temporal cortical areas [19, 20].

1.3. Normative development in early childhood

Meanwhile, attempts to reveal the peculiarities of impaired social development at the early stages detected the lack of the data on the normative trajectory of the maturation that resulted into increased number of publications in this field. Tsang et al. [21] found the connection of selective social attention (to the mouth on talking face), being one of the basic mechanisms of learning language in infants, with the concurrent expressive language rate, but not discrimination of emotions in the second half of the first year of life. Perception of the faces is another complicated aspect of social development rapidly evolving during first year of life of healthy infants [22]. According to the results, obtained by Lloyed-Fox et al. on a group of 5-month-old babies in fNIRS experiments, infants' brain response differs for the social and non-social stimuli. Observed bilateral metabolic changes in temporal sites are interpreted as the activation of superior temporal sulcus (STS), reported to be involved in processing of dynamic social stimuli [23].

The EEG studies of 9- and 14-month-old babies observing actions of the other people (that is strongly associated with social attention) demonstrate desynchronization at frontal, central and parietal sites within 6–9 Hz frequency band (considered to be functional analogue of mu rhythm in adults), and more localized central desynchronization during execution of actions by baby [24, 25]. Similar results were obtained by Jones et al (2015) in the EEG study, aimed to register brain activity during observation of social and non-social video-recorded scenes. Authors additionally emphasize dynamical increase in the power of socially selective theta activity with age: from 6 to 12 months [26].

1.4. Summary

The aforementioned behavioral and neuroimaging data demonstrate that such components of social development, as social attention, face and biological motion perception, child-parent interaction, as well as their effect on the following development, have been studied in preterm comparing to full-term children. Most of the experiments demonstrated delays in the development of the component or altered pattern of functioning.

Dynamic social stimuli change metabolic and electrophysiological activity in right and left temporal lobe in typically developing full-term children, while observation of social and non-social movements (mostly requiring attention) affects frontal, central and parietal lobes. Neuroimaging data based on the registration of cortical activity in preterm infants demonstrate alternations in theta and alpha synchronization in frontal and central sites during social attention tasks. Thus, most studies depict executive component of social cognition in preterm infants and toddlers.

However, the number of studies demonstrating differences in perception of social and non-social stimuli by the means of electrophysiological methods in preterm and full-term infants and toddlers is scarce.

2. Methodology

2.1. Participants and protocol

For the longitudinal study we plan to enroll at least 80 participants, taking into consideration 35–50% drop-off for the infants [24, 25, 27]. All the participants will be split into a control and an experimental groups. A control group will comprise full-term (gestational age > 37 weeks) congenital healthy 10-month-old infants. An experimental group will comprise the same amount of preterm infants (gestational age 28–36 weeks, birth weight > 1 kg, absence of malformations of brain, heart and other internal organs; absence of hemorrhage and hypoxic injury of any localization and rated by the results of neurosonography; absence of hyperbilirubinemia or any intrauterine infection) matching the controls according to the corrected age and socio-demographical features. The participants of both groups will be assessed according to the longitudinal protocol at the age of 10, 14 and 24 month of the controls. The study is approved by the Local Ethical Committee of the Ural State Medical University. As the participants are enrolled in the study and for every visit the informed consent forms are being signed by the child caregiver.

2.2. Stimuli

In a study are used social and non-social full-color stimuli, adopted from similar to the reported by Lloyed-Fox et al. [23]. The 'social' stimuli presented one-minute block of a series of the video-recorded short rhymes visualized and pronounced by female actors, which are culturally specific for parenting in Russian families during early childhood. The female actors (on video are only head and shoulders) use the means helpful in maintaining attention of infants and toddlers, such as enlarged hand-play, increased mouth and eye expressions, and voice intonation. The 'non-social' stimuli presented the video combination of moving toys in a full-screen size, mostly surrounding babies in their everyday activity. This block lasts approximately one minute and is counter-balanced with social one in amount of motion.

2.3. Procedure

After the EEG-cap is placed on a child head with the help of caregiver and entertaining procedure in a comfortable playing room, they move to the sound-proof shielded room. Here the child is placed on the caregivers' lap for the duration of all the assessment in front of the computer monitor, placed at a distance approximately 100 sm away of baby eyes. First, a back-ground activity during presentation of monotonous calming music and video sequence is recorded at least for 30 sec. Second, the social and non-social stimuli are performed twice during an assessment in a between subject randomized order. Though, changes in stimuli aim to maintain child attention all the time on within the experimental procedure except 3–5 sec breaks between blocks, if a child is exhausted or tired, assessment terminates. All the stimuli are presented with the Matlab script. The EEG data are acquired with high-density HydroCel Geodesic Sensor Nets (128 channels), Net Amps 300 amplifier, and Net Station, Version 5.0, software, within 0.1 to 100 Hz frequency range and vertex (Cz) reference, at a sampling rate 500 Hz. Child behavior is followed by the assistant through the video camera and recording is synchronized with EEG.

2.4. Data processing

At the first step the behavior of a child and quality of the EEG recordings are assessed. In case a baby moves a lot, does not look at the monitor, weeps or shows strong emotional reactions (e.g., laughing), as well as a caregiver talks to the baby or shakes to come him/her down, the part of a recording is rejected from the analysis. The recordings having more than 20% of bad quality channels or less than 40 sec of the data in one of the experimental (social/non-social) conditions free of rejections are excluded from the further analysis.

High- and low-frequency filtering with cutoff at 1 Hz and 45 Hz, respectively, will be followed by automatic and visual artifact detection procedures. The Fast Fourier Transformation will be applied for a 3 to 45 Hz frequency range for each condition separately. Further, the average EEG power will be calculated for each of the following frequency bands: theta (3–5 Hz); alpha (6–9 Hz); beta (13–19 Hz); gamma1 (21–30 Hz); gamma2 (31–45 Hz) and then averaged for the following groups of channels: left and right posterior temporal (LPT and RPT); left and right anterior temporal (LAT and RAT); occipital (O); parietal (P); fronto-central (F-C). Additionally, will be applied Time-Frequency Analysis independently for each condition following by the procedure described by Kotchoubey and Pavlov [28]. The repeated measures of variance (ANOVA-RM) with alpha level of 0.01 will be used for statistical analysis of the data for each of the mentioned above frequency range. The condition-dependent analysis will be performed for all three conditions: 'back-ground', 'social' and 'non-social' – with a GROUP as between-group factor (2 levels: preterm and full-term) and several within-group factors: ELECTRODE

SITES (7 levels: LPT, RPT, LAT, RAT, O, P, F-C), CONDITION (3 levels: social, non-social, back-ground) and AGE (3 levels: 10, 14 and 24 months).

3. Hypothesis

Based on the neuroimaging data obtained in typically developing infants and toddlers, as well as children at high-risk for neuro-cognitive disorders, we expect: (1) to find differences in brain activation for social and non-social conditions, presumably, in temporal electrode sites; (2) to detect delays in maturation of the areas, responsible for social cognition in preterm infant in all ages, which would be observed as increased amplitudes of response and level of synchronization/desynchronization; (3) nonetheless, to observe dynamical longitudinal changes in activation of specific 'social' areas of the brain either in preterm, as well as in full-term infants.

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