Perception of pro- and antisocial behavior by children: modulations of EEG alpha and beta rhythms

*Lilia Orekhova, Anna Mikhailova, Aleksandr Kulichenko, and Vladimir Pavlenko**

V.I. Vernadsky Crimean Federal University, 295007 Simferopol, Russia

Abstract. The paper surveys the behavior and psychophysiological responses (electroencephalographic power modulations of the alpha and beta rhythms) in 16 boys and 33 girls aged from 1.5 to 3.5 years when they were distributing reward tokens (carton cookies) among the toy characters who previously demonstrated pro- and antisocial behavior (rendering help and causing harm, respectively). The individual way of distributing the reward was translated into a moral evaluation index (MEI) for each child. When children were distributing the reward tokens, an increase in power, relative to the baseline, was registered for theta rhythm in the prefrontal, frontal and occipital cortex regions, and for beta rhythm - in the temporal and occipital regions. Besides, those children who tended to give a bigger reward to the good-acting toy character (i.e., having higher MEI) showed a significantly greater increase in beta rhythm power compared to the children with lower MEI. The reason for that might be that children with higher MEI engage their cognitive resources into making socially significant decisions more effectively and adequately process emotionally significant information.

1 Introduction

The formation of moral behavior gets its start in the earliest months of a child's life [1]. A considerable number of studies demonstrate that during infancy children can already try to comfort other people if they look frustrated [2]. It was shown that, starting from the age of 18 months, children are already capable of discriminating between pro- and antisocial behaviors demonstrated by interacting toy characters, as evidenced by how they chose to distribute the given reward tokens between them [3]. Despite a considerable amount of research in the field of the phenomenology of moral behavior, the knowledge of the neuro- and psychophysiological mechanisms underlying such behaviors in early childhood is still far from being satisfactory. Of particular interest are the patterns of the EEG beta and theta rhythm power changes in children when they make decisions on how to distribute the given reward, relative to their background EEG activity. It is shown in many studies that an increase in theta rhythm power may reflect the activation of processes related to memorization and emotional regulation. Besides, the growth of theta rhythm power can

* Corresponding author: vpav55@gmail.com

also be observed during the perception of emotionally significant stimuli [4]. The increase of the beta rhythm power can often be seen in the process of making socially significant decisions, as well as when subjects observe the emotions of other people [5].

Based on the mentioned data, the aim of our study was to examine the patterns of the EEG theta and beta rhythm power changes in children when they distribute reward, compared to their background EEG parameters. In addition, we analyzed the relationship between the EEG rhythmic power changes in children and their ability to evaluate the toy character behaviors.

2 Methods

The study involved 49 children (16 boys, 33 girls) aged from 16 to 42 months. The mean age was 31.1 ± 5.6 months. The criteria for exclusion were medical records on genetic diseases, diseases of the central nervous system, left-handedness (with an obvious predominance of the left hand when manipulating objects and when drawing). The parents gave their written consent to participate in the study. The study was consistent with the ethical principles of the Helsinki Declaration and approved by the ethical committee of the Federal State Autonomous Educational Institution of Higher Education "V.I. Vernadsky Crimean Federal University" (protocol No. 12 dated 06/14/2016).

To determine the child's moral evaluation index (MEI), we used the modification [6] of the method used by Kenward & Dahl [7] designed to measure the level of moral development in early childhood by the assessment of how children distribute reward (cartoon cookies) among the toy characters. Each child observed two scenes showing the interaction of three puppets who demonstrated "neutral", "good" and "evil" behaviors. Both scenes started with the "neutral" puppet climbing up the stairs, but in the middle of the way up it started showing difficulties in getting up to the next step (the experimenter uttered the phrase "Oh, I'm so tired. I wish there was someone to help me."). In the first scene, the "good" puppet helped the "neutral" one to step up. In the second scene, the "bad" puppet pushed the "neutral" one down the stairs with the latter puppet saying "Oh! It so much hurts!" After that, the children were suggested to evaluate the behaviors of the "good" and "bad" puppets by distributing the five carton-made "cookies" between them. The given instruction was "Give the cookies to the puppets the way you like".

The individual index of moral evaluation (MEI) was calculated based on the 20-point scale meeting the following criteria. The child was given the maximum score (20 points) if he/she rewarded the "good" puppet with all the cookies. The minimum score (1 point) was attributed to those children who gave all the cookies to the "bad" puppet. The rest MEI values depended on a specific way of distributing the reward. For example, 15 points was given to a child who had rewarded the "good" puppet with three cookies and the "bad" one – with the two, while leaving nothing for him/herself. Based on each individual score, the children were divided into two groups: for those having a relatively high MEI (15-20 points, showing the preference in rewarding the "good" puppet) and those who scored lower on MEI scale (1-14 points, meaning they either better rewarded the "bad" puppet or distributed the cookies equally between the two puppets).

The baseline (background) EEG was recorded at 16 electrodes with the help of the Mitsar-EEG-10/70-201 encephalograph under condition of a sustained visual attention (the children focused attention on a computer monitor screen showing the video of rotating geometric figures) and in the process of moral evaluation of the puppets' behaviors (each record duration equaled to 20-30 seconds). The EEG fragments were Fast-Fourier transformed with the 50% overlap for the epochs of 2.56 seconds.

The EEG parameters were calculated in individually defined frequency ranges. The upper border for theta rhythm and the lower border for beta rhythm were defined based on

the previously determined mu rhythm frequency range. The latter was defined by examining the patterns of its desynchronization in the leads C3 and C4 when executing self-paced hand movements in the test of “action perception and repetition” [8]. Following the known literature data [9], the lower frequency border for theta rhythm was set to 3 Hz and the upper border for beta rhythm – to 18 Hz. The power values for each rhythm were log-transformed to better normalize their distributions. The outliers that went beyond three sigma limits were discarded. To estimate the differences in the EEG patterns recorded at baseline and when distributing the reward, repeated measures ANOVA was implemented.

Results. The differences in the EEG powers at baseline and when distributing the reward were estimated by means of the two-factor ANOVA, with the main factors being the SITUATION (baseline vs reward distribution) and LOCUS (16 EEG electrodes). For theta rhythm, we found a significant interaction between these factors SITUATION × LOCUS ($F_{15,480}=5.197$, $p= 0.000$). Implementing the method of individual contrasts showed a significant increase in theta rhythm power at the electrodes Fp1 ($F_1= 5.058$, $p= 0.03$), F3 ($F_1= 5.072$, $p= 0.03$), F7 ($F_1=8.221$, $p= 0.007$), F8 ($F_1=5.436$, $p= 0.02$), O1 ($F_1=6.646$, $p= 0.01$) and O2 ($F_1=10.326$, $p= 0.003$), relative to the baseline (fig. 1). For beta rhythm, we also found a significant interaction between the main factors SITUATION × LOCUS ($F_{15,480}=4.378$, $p= 0.000$). When distributing the cookies, the children showed an increase in the beta rhythm power at the electrodes T5 ($F_1=21.137$, $p=0.000$), T6 ($F_1=19.834$, $p= 0.000$), O1 ($F_1=7.463$, $p= 0.01$) and O2 ($F_1=11.087$, $p= 0.002$), relative to the baseline (fig. 1).

Figure 1. The EEG power values for theta (A) and beta (B) rhythms at baseline (lighter columns) and when distributing resources (darker columns). The X-axis marks the EEG electrodes, the Y-axis – the means and standard errors for the rhythm powers ($\lg P$, μV^2). The significant differences between the situations are marked with asterisks: * $p \leq 0.05$; ** $p \leq 0.005$.

Next, we analyzed the differences in the EEG power changes under condition of the reward distribution, based on the main factors GROUP (lower MEI group vs higher MEI group) and LOCUS. For theta rhythm, no significant effects were found. For beta rhythm, we discovered a significant interaction effect between the factors LOCUS $\times$ GROUP ($F_{15,540}=2.117$, $p=0.008$). Though the method of individual contrasts did not reveal any specifically significant differences in beta rhythm power changes between the groups at separate electrodes, the overall trend for the whole set of electrodes showed a more pronounced beta rhythm power increase in the process of decision making on how to reward the toy characters in the higher MEI group of children, if compared to the lower MEI group.

Discussion. The present study was dedicated to examining the neurophysiological correlates of moral behavior in early childhood. We analyzed specific changes in the EEG parameters when the children were distributing the rewards, relative to the baseline condition. We discovered a significant increase in theta (in prefrontal, frontal and occipital regions) and beta (in temporal and occipital regions) rhythm power under experimental condition relative to the background EEG.

It is thought [4] that the effect of theta rhythm activation is related to the processes of memorization and retrieving emotional information from the long term memory. It can be hypothesized that, under experimental conditions, children heavily relied on their memory in the process of deciding on how to reward the toy characters.

The beta rhythm activation is associated with the process of decision making [10]. In our study, we established that the beta rhythm power was significantly more pronounced in children with higher MEI. Researchers [4] associate the effect of beta rhythm activation with the “delayed index of cortical activation”. In neocortex, the beta activity is likely to represent the process of its resetting following the effects of a strong activation in neural networks, allowing to keep up with the flow of information processing. As a result, information processing becomes more efficient and decision-making is more adequate. It can be hypothesized that children with higher MEI tend to demonstrate a more pronounced increase in beta power exactly because they are able to more effectively engage their cognitive resources and adequately process relevant information when making socially important decisions.

3 Conclusions

1. The theta and beta rhythm powers were found to be significantly higher in children when they distributed the given reward among the toy characters, relative to the baseline condition. We hypothesize that this type of task heavily recruited their memory resources and demanded better understanding of a social context needed to make a proper decision.

2. The children with higher MEI demonstrated a significantly increased level of beta rhythm power compared to the lower MEI children in the process of reward distribution. We assume that children with high MEI are more efficient in recruiting their cognitive resources when making socially relevant decisions and are capable of a more adequate processing of emotionally significant information.

The reported study was funded by RFBR, according to the research project № 18-015-00074 a

References

1. L. Young, J. Dungan, Soc. Neurosci. **7**, 1 (2012)
2. M. Svetlova, S. Nichols, C. Brownell, Child Devel. **81**, 1814 (2010)
3. M. Paulus, C. Moore, Advan. in Child Devel. and Behav. **42**, 271 (2012)
4. J. Kropotov, *Quantitative EEG, Event-Related Potentials and Neurotherapy* (Academic Press, 2008)
5. M. Pratt, A. Goldstein, R. Feldman, Soc. Cogn. Affect. Neurosci. **13**, 957 (2018)
6. L.S. Orekhova, Probl. of mod. pedagog. educat. **54**, 345 (2017)
7. B. Kenward, M. Dahl, Devel. Psych. **47**, 1054 (2011)
8. V.B. Pavlenko, Yu.O. Dyagilieva, A.A. Mikhaylova, V.V. Belalov, S.A. Makhin, E.V. Eysmont, The J. of Fund. med. and biol. **2**, 30 (2016)
9. T.A. Stroganova, E.V. Orekhova, I.N. Posikera, Clin. Neurophysiol. **110**, 997 (1999)
10. J. Cannon, M.M. McCarthy, S. Lee, J. Lee, C. Börgers, M.A. Whittington, N. Kopell, Eur. J. Neurosci. **39**, 705 (2014)