EEG Study of the Disgust and Pleasant Stimuli Perception in 5-6 Years Children and Adults

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ABSTRACT

The perception of visual emotional stimuli develops during the human ontogeny. The purpose of this study is to find developmental electrophysiological changes in human emotional perception. We compared EEG power spectrum density recorded in 5- to 6-year-old children (N=27) and adults (N=28) in response to different pleasant, disgust and neutral visual stimulation, including severely damaged human faces, food, insects, snakes, kids, animal cubs and neutral stimuli. Brain electrical activity was recorded using a 19-channel EEG recording device, "Encephalan", with the recording of polygraph channels. Fast Fourier Transform (FFT) was used to analyze the frequency spectrum (2-3 Hz, 3-4 Hz, etc., 19-20 Hz). The beta-and theta-rhythm power was higher compared to background in children and lower in adults during presentation of images of damaged human faces, insects, and snakes. The ECG heart rate was significantly higher during damaged faces presentation compared to the background only in children. Our findings indicate that the perception of damaged human faces excludes empathy component of perception in children.

Key Words: Electroencephalography, Fast Fourier Transform, Pleasant and Unpleasant Stimuli, Ontogeny, Empathy.

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Introduction

Well known, that visual perception of the emotional stimuli develops as the child matures. Newborns do not distinguish facial expressions, but seven-month-old children do recognize happy and sad faces as distinct emotive categories (Leppanen et al. 2009; LeDoux, 2000). The most developmental changes in visual perception take place only by 9 years of age (Farran, 2008). Some visual-cognitive abilities, especially related with social information, are not developed in 5-6 years children (Spelke, 1981). This development occurs through perceptual learning, when children accumulate information from the environment as they explore social events, faces, emotions.

Mimic recognition is necessary to develop social interaction or communication. Investigation of the brain electrical activity during this emotional stimulation demonstrates its variability depending on stimulus type, for instance, perception of the positive/negative facial expression or damaged faces aroused a reaction principally in the right hemisphere (Kayser et al. 1997; Laurian et al. 1991). The facial expression perception is a difficult process occurred in activation of various areas involved interactions between different brain regions. (Vuilleumier & Pourtois, 2007). For example, the facial expressions of fear activate a large number of areas, modulated by the amygdala and fusiform gyrus: occipital cortex, superior temporal sulcus, cingulate gyrus and parietal cortex. (Nicholls et al. 1999; Cahill & McGaugh, 1998).

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Previous studies showed that the left hemisphere process dominantly positive facial expressions and the right hemisphere - negative facial expressions (Sackeim et al. 1982; Phillips et al. 2001).

With the raising interest for emotion brain device, user's EEGs have been developed the new path for identify a specific EEG-pattern of the emotion (Lang, 1993; Murugappan, et al. 2008). The expressions of fear and anger cause the most significant and diverse brain activation. Thus, different research showed, that the higher ventromedial cortex activation during food images presentation was found in subjects of particular relevance to food (James et al. 2007). Other research, in which subjects were offered to examine photos of patients with the started dermatological diseases, shows the N2 and P3 components' amplitude acceleration most pronounced in the right parietal area (Kayser et al. 1997). The research of the human facial expression perception showed, that subject's emotional responses are independent of the human individual features.

As was showed previously, young children are able to identify negative facial emotions but cannot identify the difference between face showing disgust, anger or other negative social emotions. Meanwhile, children by ten years old already are able to make the distinction between disgust and negative emotions (Hayes, 2009). The appraisal of social interaction and exploratory activity as well as conversational abilities in children 4-5 years makes the children of this age to be important for the research of development of disgust visual stimuli perception. Preschool children in spite of language difficulties can evaluate and express their feelings as well as assess other's emotions, which might be useful for the formation of preschool arrangements (Jacobson, 1979).

Methods

Participants

28 healthy adults (12 males and 16 females) and 27 children (14 boys and 13 girls) participated in this study. The adult subjects were aged 20 to 36 years (mean age = 24.6 years), and the children were aged 5 to 6 years (mean age = 5.56 years). The parents gave informed consent as approved by the Ethics Committee. All of the participants were right-handed, and none of the subjects were reported to have any seizure-related disorders, to have vision problems, or to be taking any medication. This research performed in the Human Higher Nervous Activity Lab, in Institute of Higher Nervous Activity and Neurophysiology of RAS (IHNA&NPh RAS), after approval by the institution's Research Ethics Committee (N 111). All parents gave informed consent as approved by the Ethics Committee before study participation.

Stimuli and Procedure

Stimuli were presented via monitor at the center of the screen. The IAPS (International Affective Picture System) was used (Bradley & Lang, 2007) to choose 5 types of stimuli:

1) Pleasant:
   - healthy happy faces of children and adults,
   - food (fruits, ice-cream)
2) Disgust:
   - crushed ugly faces of children and adults after mechanic trauma, burns, radiation
   - images of insects and snakes.
3) Neutral
   - neutral objects (furniture)

The small 0.35 x 0.5 angle (500 ms) degrees cross was used for the fixation of the view and which disappeared during relevant stimuli presentation. Each type of stimuli was presented 20 times. Stimuli generation was synchronized using Presentation Software (Neurobehavioral Systems). A series of pictures were presented in a pseudo-randomized sequence. The pictures were 1024x768 pix, their duration were 15 seconds.

Psychological tests

All subjects were tested by the group of the experts-psychologists using different tests (Pediatric Behavior Rating Scale (PBRS), Test MMPI, The Empathy Quotient test (EQ)). We conducted our research to analyze the reactive feelings and emotional stated caused by the emotional stimuli presentation. Adult Subjects were asked to assess the visual stimuli using the list of the emotional states (Izard, 1991; Ekman, 1999), and self-reporting. The similar self-reporting procedure was conducted in children sampling using conversation methods.

EEG registration

During the EEG recording the subjects sat in a comfortable position in an armchair in an acoustically and electrically shielded chamber. The participants were instructed to remain calm, with their eyes closed or opened, to avoid falling asleep and to avoid thinking about anything specific. Brain electrical activity was recorded

using a 19-channel EEG recording device, "Encephalan", with the recording of polygraphic channels (Poly4, Medikom MTD, Taganrog, Russian Federation). The amplifier bandpass filter was nominally set to 1.6-30 Hz. Continuous EEG was acquired with AgCl electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, O2) according to the International 10–20 system with a sampling rate of 250 Hz. The electrodes placed on the left and right mastoids served as joint references under unipolar montage. The vertical electro-oculogram (EOG) was measured with AgCl cup electrodes placed 1 cm above and below the left eye, and the horizontal EOG was measured with electrodes placed 1 cm lateral from the outer canthi of both eyes. The electrode impedance was maintained at less than 10 kΩ. The ECG was measured and synchronized with EEG.

Data analysis

The EEG signals were cleaned from eye movements according to the EOG data with the "Encephalan" software. Small intervals affected by muscle activity were excluded manually using visual inspection. All the following processing was performed using EEGLab (James et al. 2007) plugin for MatLab (Mathwork Inc.).

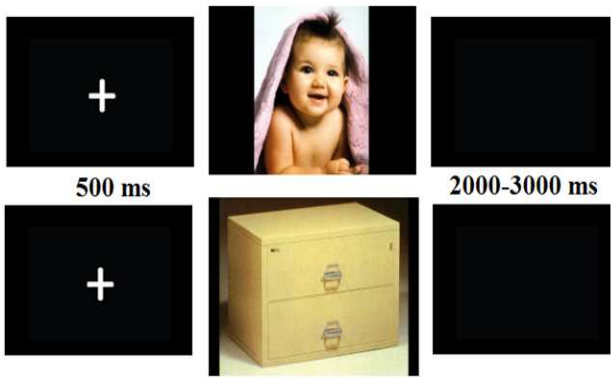
Spectral Analysis

Fast Fourier Transform (FFT) was used to analyze the frequency spectrum and phase differences. The resulting spectra were integrated over intervals of unit width (2-3 Hz, 3-4 Hz, etc., 19-20 Hz). These values were statistically compared between groups and their correlations (with significance) with age were calculated. The resulting waveforms are displayed as a brain map to show the power distribution within each frequency band. FT is applied to different visual type of the EEG signals (these signals are obtained from the same subject and during the same task).

Statistical analysis

The EEG data were analyzed with Matlab 7.11.0 (Mathwork INC) and the EEGLAB 9_0_4_6s plugin for Matlab. Ocular artefacts were removed from the data using independent component analysis (ICA). The blink-related components were identified on the basis of their waveform, scalp topography and frequency spectra.

Statistical analyses were performed using "Statistica 6" (StatSoft) and Matlab 7.11.0 (Mathwork INC). First, the data was analyzed using T-test for each channel, each type of stimuli, compared to the background. The differences within and between stimuli/groups were considered statistically significant at $p < 0.05$. A repeated measures ANOVA with Bonferroni correction for multiple comparison, $p < 0.05$, was completed to determine grope effects.



Picture 1. The experimental scheme with 2 stimuli types (healthy faces and neutral object)

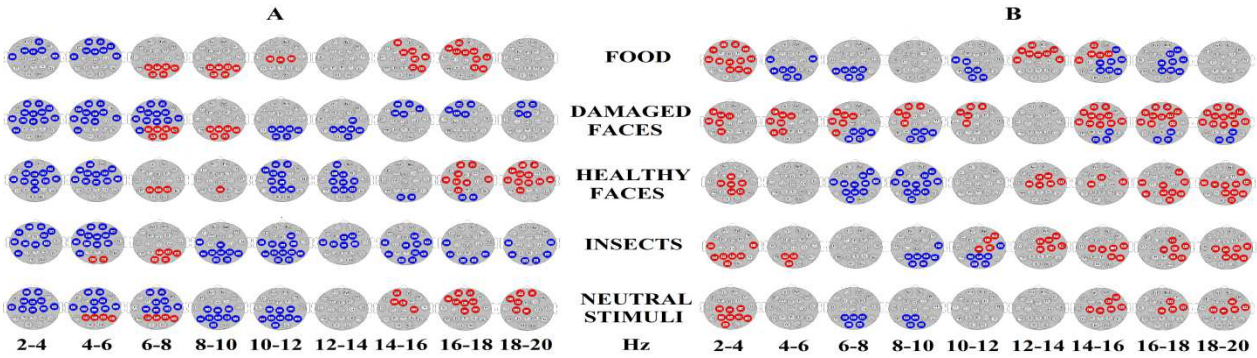
Results

The adults' perception of food, damaged faces, healthy happy faces, snakes and insects neutral stimuli was characterized by variable rhythmic changes compared to background (Pic.2A). As well The children' perception of food, damaged faces, healthy happy faces, snakes and insects neutral stimuli was also characterized by variable rhythmic changes compared to background (Pic.2B). The emotional assessment of stimuli in healthy adults and children is presented in table1.

The ANOVA statistics showed significant grope differences between adults and children during perception of stimuli: During the food presentation the delta-rhythm power was higher in children compared to adults in frontal area lower ($F(1, 54)= 8.9148$, $p=.00129$), the theta-rhythm (6-8 Hz) was lower ($F(1, 55)= 6.2128$, $p=.0036$) in parietal-occipital areas. During the damaged faces presentation the delta- (2-4 Hz) and theta-rhythm power (4-8 Hz) was higher in the left temporal and frontal area in children compared to adults ($F(1, 55)= 14.625$, $p=.00023$), the theta-rhythm power was lower in parietal-occipital areas in children compared to adults ($F(1, 55)= 9.045$, $p=.00834$), the beta (14-20 Hz) - rhythm power (4-8 Hz) was higher in the frontal area in children compared to adults ($F(1, 55)= 7.312$, $p=.00734$). During the healthy faces presentation the delta-rhythm power was higher in children compared to adults in central area ($F(1, 55)= 6.551$, $p=.00651$).

Table 1. The stimuli assessment by healthy adults and children (psychology testing and self-reports, %)

healthy adults									
Damaged faces		**food**		**Healthy happy faces**		**insects and snakes**		**Neutral stimuli**	
Empathy	100%	Want to eat	100%	sympathy	93%	vomiting	93%	calm	58%
pity	93%	appetite	93%	pleasure	73%	disgust	93%	"not sure"	34%
affliction	93%	hunger	93%	happiness	66%	abhorrence	80%		
desire to turn away	93%	pleasure	93%	cuteness	59%	nausea	80%		
pain	73%	excited	84%	joy	53%	desire to turn away	73%		
disgust	73%	happiness	47%	desire to hug	53%	excited	68%		
vomiting	61%	tasty	46%			fear	51%		
nausea	58%								
children									
Damaged faces		**food**		**Healthy happy faces**		**insects and snakes**		**Neutral stimuli**	
		tasty	73%	pleasure	53%	fear	65%	"not sure"	51%
fear	87%	hunger	73%	sympathy	49%	terrible	60%		
Terrible	80%	appetite	67%	happiness	46%	disgust	53%		
disgust	73%	pleasure	53%	joy	33%	abhorrence	33%		
frighten	73%	Want to eat	53%	"not sure"	20%	desire to turn away	23%		
desire to turn away	67%								
pity	26%								



Picture 2. The t-test significant differences (p<.05) between the stimuli and the background averaged EEG rhythmic spectrums in each EEG channel, for each stimuli type in children. The red color means higher rhythmic power compared to the background and the blue color - lower. A: adults B: children

During the insects and snakes presentation the delta- (2-4 Hz) and theta-rhythm power (4-6 Hz) was higher in the left temporal and frontal area in children compared to adults ($F(1, 55)= 8.335$, $p=.00198$), the 12-14 Hz-rhythm power was higher in children in central areas ($F(1, 54)= 4.954$, $p=.0195$). During the neutral stimuli presentation the delta-rhythm power was higher in children compared to adults in central area ($F(1, 55)= 5.0821$, $p=.0285$). The higher mu-rhythm power in children compared to adults was found for all emotional stimulation ($F(1, 55)= 11.472$, $p=.00512$) but not for neutral stimuli. The ECG hart rate was significantly higher during damaged faces presentation compared to background in children ($p<0.05$). The hart rate values in children correlated with theta-rhythm power (4-8 Hz) in the left temporal area ($p<0.05$). The correlation analysis between psychological test and the EEG data didn't show significant results.

Discussion

Our results showed the existence of the age differences in the emotional perception between children and adults, which were most pronounced for unpleasant images. During perception of images with damaged faces the adults showed lower beta-rhythm and delta- and theta-rhythm power in the frontal areas compared to the background, in children it was higher. The EEG group differences were accompanied by

psychological differences such as empathy that was found only in adults.

The previous data showed that higher theta-rhythm power was usually found during significant emotional stimuli perception and was specific for patients with panic disorder (Rabe et al. 2006) and patients with anxiety (Buchsbaum et al. 1985). Meanwhile, vegetative data, such as heart rate values, which were significantly higher during damaged faces presentation, can be related with state of emotional strain in children. In adults the images of damaged faces produced emotional response accompanied by empathy feelings. Our results approve data of other studies, showed that newborns become distressed when they hear other infants' crying, and they pay close attention to our emotional signals, but ability to feel or imagine another's emotions develops in children about 5 years (Martin & Olson, 2013).

Age differences of the EEG patterns during damaged faces images perception were most pronounced in the frontal areas. The previous studies showed, that the lack of empathy as personality change which are similar to psychopathic personality traits was found in patients with focal lesions in the vmPFC (Motzkin et al. 2011). Research using fMRI has implicated the medial, dorsal medial, ventromedial and ventrolateral prefrontal cortex in empathy.

We found that mu-rhythm was higher in children compared to background in response to emotional stimuli and wasn't found during neutral stimuli perception. Meanwhile, in adults we found mu suppression over sensory-motor region in response to emotional stimuli with social component (healthy and damaged faces). Recent studies demonstrated that EEG mu suppression appears to social information processing, including social skills (Pineda, & Hecht, 2009) and empathy (Cheng et al. 2008; Yang et al. 2009). The acceleration of the mu-rhythm in children could be explained by the motor action during emotional stimuli perception, which was suppressed in adults. As was showed earlier the mu rhythm was originally conceived to reflect a cortical ''idling'' or ''nil-work'' state, similar to the classical alpha-rhythm (Mulholland, 1995; Pfurtscheller et al. 1996) it has no striking psychological correlates and appears to reflect the translation of perception into action (Kuhlman, 1978; Goren et al. 1975).

The perception of food in children was accompanied by higher delta-rhythm power and lower theta-rhythm power compared to adults. The research of the appetizing food odors showed significant changes of the theta-rhythm power compared to no-odors and nonfood odors [Martin, 1998]. The appetizing stimuli evaluation induces the sequential activation from the temporal cortex to the ventromedial prefrontal cortex (Harris et al. 2011). The appetite regulation also corresponds to the ventromedial prefrontal cortex activation related with food value (James et al. 2007). The prefrontal activation (by the beta-rhythm acceleration) was higher in adult. Thus, it's possible to suggest that the food was assessed as appetizing stimuli more by adults. Furthermore, adults possibly have more developed food value compared to children.

Limitations

We understand, that the number of participants is limited (27 children and 28 adults). As part of our research strategy, we have chosen preschool children as a promising area of interest to find developmental changes in human emotional perception.

Conclusions

1. The most pronounced differences during the perception of damaged faces were found in the frontal and left temporal areas and were accompanied by higher stress in children and empathy in adults.
2. The age-related differences during damaged faces perception was correlated the ECG heart rate in children.
3. Mu-rhythm was higher in children compared to background in response to emotional stimuli with a social component; in adults mu suppression over the sensory-motor region was found.

Recommendations

Further research could also be conducted to determine the differences of disgust stimuli perception in school age children and patients with ASD. Moreover, we are going to extend the number of participants with school-age children and preschoolers (2 to 4 years).

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