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Defects in automatic processing of auditory channel brain information in children with developmental dyslexia

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Abstract

Using event-related potential (ERP) technology to explore the characteristics of automatic processing of auditory brain information in children with developmental dyslexia and control groups in the state of non-attention. Selecting 18 children with developmental dyslexia and 18 children in the control group (male 21, female 15). The experiment presents a total of 300 sound stimuli, and auditory stimuli are divided into two kinds of 1000HZ and 1500HZ. The visual stimulus was 300 yellow and green car graphics. The participants were asked to recognize the color of the pictures and prepare for the keys. When testers see the green car, the left index finger presses the Z key, and when testers see the yellow car, the right index finger presses the M key. Presented on the headset do sound stimulus signal response. Recording 32 channel EEG, and analyzing the amplitude and latency of auditory mismatch negative waves (MMN) in different groups of subjects. The N1 amplitude of the developmental dyslexia group was significantly greater than that of the control group. At all electrode positions, the P3 amplitude of the control group was greater than the developmental dyslexia group. The right side of the auditory MMN amplitude of the control group is greater than the left side, and there is a right side advantage, while the left and right MMN amplitudes of the developmental dyslexia group are similar, and there is no right side advantage.The developmental dyslexia group spent more cognitive resources in the early pre-attentive processing stage, which led to the lack of attention resources for subsequent new stimuli. Developmental dyslexia children's auditory channels have defects in automatic processing of information.

Keywords: Mismatch negativity(MMN); Pre-attentive processing; Sensory memory; Developmental dyslexia.

1. Introduction

Developmental dyslexia refers to under the condition of the formal education, the standard reading test scores of typically developing children were significantly lower than the same age children, which did not include children with obvious nerve or physical damage. The researchers generally believed in the early days that Chinese children’s bad reading related to distraction in class, low interest in learning, intellectual problems and other factors. Chinese as an ideogram is different from phonetic writing system, and the children who use Chinese may not exist reading disorder problem(Shu Hua, Meng Xiangzhi, 2000). Developmental dyslexia is a common neurobehavioral disease with a prevalence of 5% -7% in school-age children.

Whether or not Chinese dyslexia exists phonetic defects is still controversial. The study of 8 to 9 years old elementary school children from Britain, Taiwan, China and Hong Kong, China respectively conducted by Huang and Hanley found that British children’s phonetic consciousness was closely related to reading ability(0.37~0.59), while the development of Taiwan, China children's Chinese reading ability had a low dependence on its phonetic consciousness ability, the predictive ability of early phonetic consciousness can only explain 0.06% variation of the late reading ability, while the early Chinese characters cognition can explain 51.07% variation. Thus, whether or not early phonetic consciousness has an impact on children's later development of reading ability is still hard to say. Hwa-Wei KO and Jun-Ren Lee（1996）also found basically consistent results with Huang and Hanley through two years of the longitudinal research. The research conducted by Chen Shuli and Zeng Shijie (1999) also indicated that children's phonetic consciousness had no necessary link on Chinese characters cognition ability. On the problem of the relationship between Chinese children phonetic consciousness and reading ability, however, some researchers also concluded the results which was not consistent with the conclusion above. Ho (1997; 1997) through 4 years of follow-up study found that early childhood phonetic consciousness skills still can predict the later development of reading ability level, even in control age, intelligence, and the mother's level of education and other factors. In a word, there has not reached a consensus on the issue of phonetic consciousness's cross-language consistency in the development of children's reading ability, and the specific role that phonetic consciousness plays in the development of Chinese children's reading ability needs further in-depth discussion.

Mismatch negativity (MMN) is an early component of ERP. It is an ERP component that does not require intentional attention before participation. It is a specific electrophysiological component reflecting the automatic processing of information by the brain. It is a valuable indicator of the brain's primary automatic processing of changes in stimulus signals （Näätänen，1988；Fisher，2012）. Related research (Wang Enguo et al., 2011) found that the negative wave of errors can be used as one of the clues to diagnose neurological abnormalities in learning difficulties. Schulte Körne et al. (1998, 1999) found that MMN induced by pure tone stimulation did not differ significantly between the adult dyslexia group and the control group. However, the amplitude of MMN induced by speech information stimulation in the disorder group was smaller than that of the MMN induced in the control group. Dyslexia is only significantly different from the control group in the processing of speech stimuli. They concluded that defects in the automatic processing of auditory information in dyslexia are related to speech perception. However, the research by Paavilainen et al. (2013) showed that dyslexia is difficult to distinguish both verbal and non-verbal sounds. They believed that dyslexia is not only a barrier to auditory processing of verbal information, but also a more general hearing processing defect.

Therefore, it can be seen that MMN about dyslexia is still controversial, and the MMN of Chinese dyslexic children is still unclear. However, compared with the research on the attentional neural mechanism of developmental dyslexia, the research on the non-attentional neural mechanism of children with developmental dyslexia is still very limited, and the conclusions drawn are not the same.This study used event-related potential technology to investigate the characteristics of automatic processing of auditory brain information in children with developmental dyslexia and the control group without attention.This study predicts that if children with dyslexia have auditory automatic processing defects, then there will be differences in the P1 and N1 early components of ERP from the control group.

2. Methods

2.1 Participants

Experimental subjects were selected from grade 1 and grade 2 students in two junior high schools. All students accepted Raven Standard Reasoning test, Chinese Literacy Quantity test and Reading Fluency test. The Raven Standard Reasoning test mainly examined the nonverbal intelligence of children. The Chinese Literacy Quantity test was mainly used to survey the word recognition level of children's reading ability. The Reading Fluency test was used to screen the children's reading comprehension ability. And all tests were measured by groups.

According to the test results, we selected the children whose scores on the Raven Standard Reasoning test was above 85, Chinese literacy quantity was below the grade a standard deviation, and scores on the Reading Fluency test was below the average scores as reading disorder group. While selected the children who had the same intelligence level, age, but whose literacy quantity and scores on the Reading Fluency test were above the average as normal control group. At the same time, the course teachers accessed the groups children according to the Learning Disabilities Children Screening table and the DSM-IV’s ADHD Screening scale, the total points on the Learning Disabilities Children Screening table was below 65, and ruled the children with attention deficit hyperactivity disorder out. We defined 36 experimental subjects formally, including 20 with developmental dyslexia and 20 in the normal control group, including 23 male students and 17 female students. All participants were healthy, had no serious disease history record, were right-handed, had a visual acuity or corrected visual acuity above 1.0, and were 10–11 years old. What’s more, they had received guardian's consents before experiment, signed the informed consents, and got certain reward after the experiment.The EEG results showed that 4 subjects had too much blinking times and artifacts. These data were excluded. Finally, there were 36 effective subjects. Among them,including 18 with developmental dyslexia and 18 in the normal control group, including 21 male students and 15 female students. This research has been reviewed and approved by the Research Ethics Committee of Henan University. The information of the subjects is shown in Table 1.

Table 1. Participant characteristics

	Control group (n = 18)		Developmental dyslexia group (n = 18)			
	M	SD	M	SD	F	P
Age	12.8	0.41	13.0	0.43	0.66	0.94
Male	10	0.74	11	0.67	0.36	0.82
Female	8	0.47	7	0.88	0.46	0.73
Intelligence	105.3	3.22	103.8	4.17	1.73	0.09

2.2 Experiment design and procedure

The experiment provided a total of 300 sound stimuli, and auditory stimuli were divided into two kinds of smooth short pure sounds of 1000HZ and 1500HZ. 240 short pure tones of 1000 Hz are used as standard stimuli with a probability of 80%; 60 short pure tones of 1500 Hz are used as deviant stimuli with a probability of 20%. Each short pure tone has a duration of 30 ms and an intensity of 50 dB. The visual stimulus is 300 green and yellow cars, including 240 green cars, 8 cm in length and 3 cm in height; there are also 60 yellow cars of the same size. Participants were asked to identify the color of the picture and prepare for key presses. The left index finger of the green car presses the Z key, and the right index finger of the yellow car presses the M key. Participants doesn't respond to sound stimulation signals presented in the headset.

2.3 Data collection

The EEG recording system produced by the German Brain-Product company is used, and the 32-channel amplifiers was used to record the EEG. The ground electrode was the midpoint on the line connecting FCz and Fz, and electrodes were placed laterally to the eyes to record the HEOG, and above and below the right eye to record the VEOG. The mastoid of the left ear was used as the reference electrode. The scalp resistance at each electrode was kept below 5 kΩ. The filter bandpass was 0.05-100 Hz, and the sampling frequency was 500 Hz. Offline analysis using the average potential of the left and right ear mastoids as a reference, and the low pass of offline filtering is 50HZ (12dB / oct). Amplitudes over ±200 V were regarded as artifacts to eliminate.

2.4 Data recording and analysis

According to the previous research experience (Schulte-Korne et al., 1998) and the purpose of this experiment, the data of 17 electrode points were selected for analysis, namely the prefrontal zone (FP1, FC1, FC2), frontal zone (F3, Fz, F4), central zone (C3, Cz, C4), temporal zone (T7, T8, P7, P8), parietal zone (P3, Pz, P4) and occipital zone (OZ). Epoch segmentation from 100ms before stimulation to 400ms after stimulation, and baseline correction 100ms before stimulating soun. The brain waves obtained by different groups in the state of auditory inattention are superimposed, and the average amplitude analysis method is used. The brain wave subtraction function provided by the Brian Products ERP analysis system software was used to subtract the standard stimulus from the deviation stimulus to obtain the MMN waveform of auditory information processing in the control group and the developmental dyslexia group. MMN is the waveform after deviation stimulation minus standard stimulation, and the peak value of the waveform is used for statistical processing. All data was analyzed by SPSS18.0 statistical software package for t-test between developmental dyslexia and control group according to correct rate and response time.

3. Result

3.1 Behavioral result

Under non-attention conditions, the response time of the visual channels of the control group and the experimental group was (417.6 ± 48.7) and (439.5 ± 57.2) ms; the correct rate (%) was 90.7 ± 5.1 and 86.4 ± 16.7. The results showed that the response time of the control group was significantly shorter than that of the experimental group, and the accuracy rate of the control group was significantly higher than that of the experimental group.

3.2 EEG data

Adopting 2 (Developmental dyslexia and control group)×17(Electrode points) repeated measures analysis of variance, the main effect of the difference between the MMN amplitude groups is significant under the condition of paying attention to sight and neglecting hearing. F（1，36）=4.66，$p<0.05$, group × electrode position main effect is significant，F（16，576）=2.45，$p<0.05$. The results of repeated measurement analysis of variance for dyslexia and the average amplitude of auditory MMN in the control group are shown in Table 2.

Table 2. Repeated measurement variance analysis of MMN average amplitude

	df	*F*	*p*
Group	1，36	12.03	0.001**
Electrode position	16，576	2.22	0.044*
Electrode position×group	16，576	2.45	0.027*

Note: * means p <0.05; ** means p <0.01.

When performing independent sample T tests on different ability groups, it was found that under inattentive auditory conditions, the MMN amplitudes in the prefrontal zone (FP1, FC1, FC2), frontal zone (Fz, F3, F4), central zone (Cz, C3, C4), and parietal zone Pz are significantly different. Further comparison revealed that the N1 amplitude at these electrode points of the dyslexic group was more negative than the control group. This result shows that the dyslexic group invested more cognitive resources in the pre-attention processing stage. At all electrode positions, the P3 amplitude of the control group was significantly greater than the developmental dyslexia group. This result suggests that the developmental dyslexia group has insufficient resources to invest in new stimuli.

There was no significant difference in MMN latency between different ability groups.

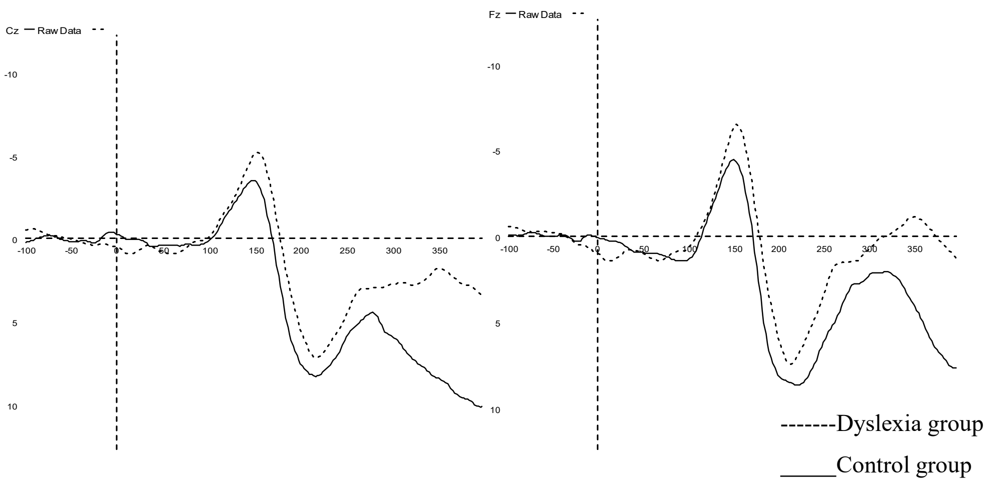

Fig.1 Comparison of waveforms of auditory MMN in dyslexia and control group with non-attention

The MMN difference wave is obtained by subtracting the auditory MMN of the developmental dyslexia group from the auditory MMN of the non-attention condition of the control group. Comparing MMN difference waves and difference wave topographic maps of different ability groups (see Figures 2 and 3) found that in the control group, a negative MMN wave appeared in the right prefrontal lobe 130 ms after the stimulus was presented, and then gradually increased. At 160 ms, the amplitude was the largest and distributed throughout the prefrontal lobe. We also found that the MMN continued until 250ms, the right side is greater than the left side. However, unlike the control group, in the developmental dyslexia group, a small negative MMN wave appeared in the left frontal lobe from about 120 ms, and then gradually increased, with the largest amplitude at 150 ms. It is mainly distributed in the prefrontal lobe and gradually shifts to the right frontal lobe, which lasts until about 140ms. The auditory channels MMN of different ability groups are distributed in the frontal lobe under non-attention conditions.

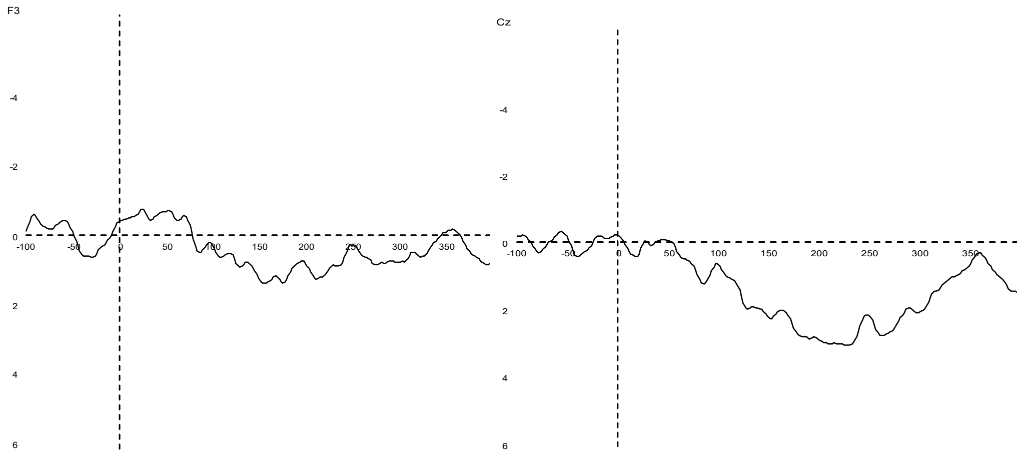

Fig.2 Comparison of MMN difference wave between dyslexia and non-attention condition of control group

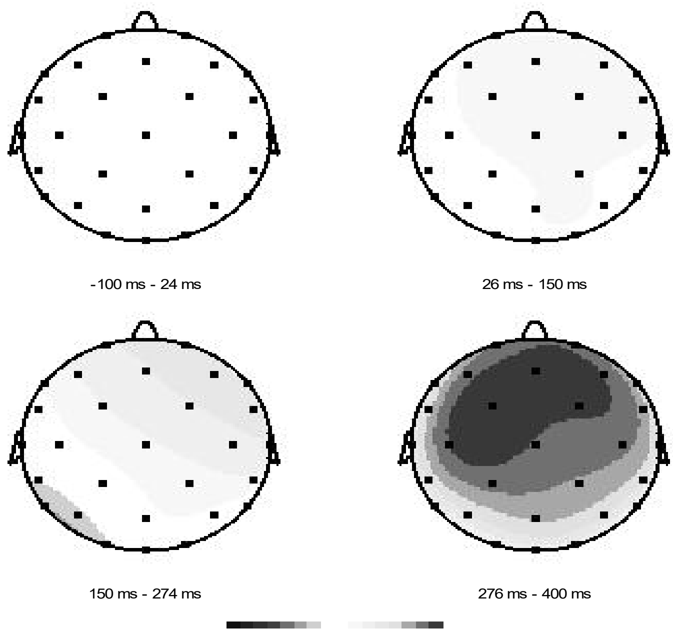

Fig.3 Dyslexia and the contrast wave topographic map of the control group with non-attention hearing

4. Discussion

In the past, most of the studies selected groups with brain function impairment as the research object, and looked for differences with normal people, and obtained valuable research results. MMN is mostly used for the study of cognitive impairment, dementia, Parkinson's disease, schizophrenia, depression and brain trauma. This study takes children with developmental dyslexia as the research object and adopts the "cross-channel delayed response" paradigm (Kujala, 2006; Fisher, 2014) to explore the characteristics of automatic processing of auditory channel brain information in different ability groups under non-attention conditions. Participants' response tasks include: attention-discrimination-preparation-response. Participants were required to focus on the stimulus signal in the visual attention channel and make the correct key response. In the gap of this reaction, the auditory stimulus signal of the non-attention channel was presented. When the stimulation of the non-attention auditory channel is presented, the subject needs to focus on the visual task. Therefore, this experimental paradigm ensures the inattention of auditory channels. Even if the stimulation interval is long, the purity of inattention can be guaranteed, which provides strong evidence in solving the debate about whether MMN is affected by attention. This study, like most studies (Guttorm, 2010; Houlihan, 2012 ,; Näätänen, 2012), obtained typical MMN in children in the control group and the developmental dyslexia group. It was also found that there was a significant difference in the MMN of the developmental dyslexia group and control group.

Related studies have found that the mismatch negative wave (MMN) is one of the clues to diagnose neurological abnormalities in children with learning difficulties. Schulte-Körne et al. (1998) found that MMN induced by pure tone stimulation did not differ significantly between the adult developmental dyslexia group and the control group. However, the amplitude of MMN induced by speech stimuli in the developmental dyslexia group was smaller than the amplitude of MMN induced in the control group. The developmental dyslexia group is only significantly different from the control group in the processing of speech stimuli. Therefore, the automatic processing of auditory information in the developmental dyslexia group is due to speech perception. However, this study used pure tone signals and found a significant difference between the control group and the developmental dyslexia group. The developmental dyslexia group has defects in automatic processing of auditory brain information.

Schulte-Körne et al. (1998) studied the difference in processing of hearing time between the adult developmental dyslexia group and the control group and found that the MMN of the developmental dyslexia group during the 250-600ms time period was significantly smaller than that of the control group. The study concluded that the developmental dyslexia group has defects in auditory processing. Based on this result, Schulte-Körne et al. (2010) believed that the nature of the temporal information in speech sounds caused the developmental dyslexia to have a smaller MMN amplitude than the control group. This means that people with developmental dyslexia have defects in the automatic processing of auditory information. This study uses the non-attention paradigm to find that children with developmental dyslexia have abnormal hearing discrimination patterns. This result supports that children with developmental dyslexia have defects in the automatic processing of auditory information. The study also found that at all electrode positions, the P3 amplitude control group was larger than the developmental dyslexia group. The results suggest that the developmental dyslexia group has insufficient resources for new stimuli, and has the deficiency of insufficient attention resource allocation. This result is consistent with the results of Kujala et al. (2003) and Russeler et al. (2002).

As can be seen from the BEAM, this study found a very interesting phenomenon. In the control group, the amplitude of auditory MMN is greater on the right than on the left. The developmental dyslexia group is different. The amplitude of MMN on the left and right sides of their hearing is similar, there is no significant difference. The results suggest that there is an abnormality in the early cognitive perception of the developmental dyslexia group, especially the cognitive process of cortical auditory processing, which may be related to unstable attention and easy transfer in the developmental dyslexia group. MMN is related to the early preprocessing of sensory information in the cerebral cortex, and reflects the activation process of the primary auditory cortex and the adjacent superior temporal gyrus. It is a specific indicator that identifies the sensory analysis, storage, and discrimination capabilities of the brain (Wacongne, 2012). In this sense, children with developmental dyslexia have sensory memory deficits. Sensory memory is the first link in information storage. Insufficient processing ability at this stage can lead to working memory deficits.

5. Conclusion

The developmental dyslexia group spent more cognitive resources in the early pre-attentive processing stage, which led to the lack of attention resources for subsequent new stimuli. Developmental dyslexia children's auditory channels have defects in automatic processing of information.

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