STUDY OF A NEW AMBLYOPIA DIAGNOSTIC AND THERAPEUTIC
METHOD ALONG WITH THE SYSTEM IMPLEMENTATION

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ABSTRACT

Amblyopia is a common visual related eye disease in childhood. Although traditional treatment to amblyopia is effective, there are still some disadvantages, such as poor compliance, easily leading to the healthy eyesight problem, the poor recovery of binocular and stereoscopy vision, the lack of objective parameter guidance, etc. Therefore, a new personalized amblyopia treatment solution is put forward to solve these problems combined with Pattern Visual Evoked Potential (P_VEP). A complete software system is built, including diagnosis module, treatment module, data management module and expert module. The EEG data acquisition and synchronized trigger circuit are designed using ADS1299 EEG Front-End and IO data collecting card to collect the raw EEG signal. Digital filtering algorithm, average superposition algorithm and wavelet algorithm are used to extract P_VEP from the raw EEG data acquired by the hardware circuit. The latency and peak of P_VEP wave is measured. The best spatial frequency is searched and obtained from the treatment training curve. It is updated automatically as treatment continues.

KEY WORDS

Amblyopia Pattern Visual Evoked Potential(P_VEP) Best spatial frequency Wavelet decomposition Average superposition

1. Introduction

Von Noorden defines amblyopia as “a decrease in visual acuity in one eye when caused by abnormal binocular interaction, or in one or both eyes as a result of pattern vision deprivation during visual immaturity, for which no cause can be detected during the physical examination of the eye(s) and which in appropriate cases is reversible by therapeutic measures”[6]. Amblyopia not only affects the patients' quality of life, study and work, but also affects the patients' mental health. Therefore, amblyopia is getting more attention and becomes the hot topic of the research.

Traditional viewpoint considers that amblyopia is caused by disintegration of the patients' binoculareceived information[6]. However, the latest researches show that amblyopia patients' neurological mechanism of binocular integrate information is undamaged. Lack of binocular visual function is mainly due to binocular imbalance input when both eyes work at the same time, rather than lack of binocular integrating ability[5].

Amblyopia is remarkably responsive to treatment if therapy is initiated early in life. However, delayed treatment can result in severe visual impairment[7,8]. Occlusion therapy with patching of the dominant eye has been the cornerstone of amblyopia treatment, despite the lack of data that demonstration its superiority over other options[9]. Atropine penalization is an alternative to patching for amblyopia therapy[10,11]. Atropine prevents the treated eye from accommodating, thus blurring the vision at near and allowing the amblyopic eye to be used preferentially. Compliance with amblyopia treatments is generally low[12].

Visual Evoked Potential (VEP) is the electric activity that is sent from visual pathway to occipital visual corthex when simulated the retina[2]. It reflects the function of the pathway from retinal ganglion cells to visual cortex. It is an objective method to detect visual pathway and widely used clinically.

Pattern Visual Evoked Potential(P_VEP) (Fig.1) is elicited by the pattern-reversal checkerboard stimulation. The clinical researches show that amblyopia patients' P_VEP latency is longer than control and peak is smaller than control. There exists a best spatial frequency in which the amblyopia eye has better P_VEP performance.

![Fig.1 Normal P_VEP wave shape](image-url)
(latency is shorter and peek is more obvious). Therefore, P\_VEP can be used for diagnosis and guiding amblyopia treatment[^3][^4].

In this paper, on the basis of the latest research about amblyopia treatment, a new personalized amblyopia treatment system is put forward combined with P\_VEP feedback to improve compliance.

2. **Result**

2.1 **Hardware design**

Amblyopia treatment system based on P\_VEP consists of PC Program, CRT monitor, skin electrodes, EEG data card (amplifier) and IO card. System composition is shown in the Fig.2.

TI ADS1299 is used as core device. This module is specially designed for EEG data acquisition. There are 8 ways differential input PGA and ADC integrated inside. EEG signal (0.5uV~100uV) can directly input to high common mode rejection ratio PGA and then be collected by ADC(24 Bit). Baseline drift filtering and trap filtering are accomplished by software.

![Fig.2 New amblyopia treatment system function chart](image)

2.2 **Software design**

Components of our solution is shown in figure 3. It includes amblyopia diagnosis system, amblyopia treatment system, data management system and expert system.

Amblyopia diagnosis system is to detect amblyopia patients' visual physiological parameters. It concludes vision inspection module, contrast sensitivity inspection module, stereoscopic vision inspection module and P\_VEP inspection module. The best spatial stimulated frequency is calculated.

Visual training system is the key part. The system can search the patients' latest best spatial stimulated frequency automatically. This best spatial frequency is used as treatment frequency. Relevant stimulation is produced by PC software. In the different treatment course, the patients' P\_VEP wave can be improved. Therefore, it can accelerate personalized treatment. Binocular balance training system sends signal to the ambyopic eye and normal eye after dealing with videos and games. It can help balance binocular suppression to make the binocular work at the same time which have better effect compared with monocular.

Data management system manages the basic information and physiological data of patients to conveniently search.

![Fig.3 Components of amblyopia diagnosis and treatment solution](image)

Specialist assistant system is formed by constantly summarizing and concluding from the amblyopia treatment and effect. It sufficiently reflects amblyopia specialists' and doctors' knowledge and experience.

This solution is a complete amblyopia treatment system that has feedback control. PC software outputs the flipping checkerboard to CRT monitor to stimulate the amblyopia patients' visual system. The wave shape is collected by ADS1299 EEG data card via skin electrodes. When PC software outputs the flipping checkerboard, it triggers synchronized square wave sent to data card as synchronized input signal. It can be used to calculate P\_VEP latency.

2.3 **Pattern Visual Evoked Potential processing Algorithm**

Average superposition is used to extract P\_VEP from original EEG signal. After repeated stimulations, the P\_VEP which has relation with time is positive increased and the noise which has no relation with time is decreased. The P\_VEP wave gradually appears from EEG. With the times increase, the SNR is improved. Considered that the patients can't bear hundreds of stimulations, twenty times is enough.

EEG signal is very weak, typically millivolt, and vulnerable to be interfered by power frequency. The analogous circuit will be very enormous if we use analogous trap filter. However, digital band-stop filter is able to flexibly adjust the cut-off frequency by software.
The collecting raw EEG data is shown in Fig.4. It consists of 20,000 points with a sampling rate of 4000.

Therefore digital fourteen-order Butterworth band-stop filter is designed. The gain is less than -80dB at 50Hz. It can effectively filter 50Hz power frequency, relatively similar with evoked potential. First, twenty times superposition and average are conducted. Then

P_VEP is extracted by wavelet transform. The specified scales of detail signal or approximate signal that can reflect P_VEP main feature to reconstruct signal to enhance the signal and depress noise is designed. Five-order Daubechies wavelet is appropriate. Its wave is wavelet decomposition with decomposition level of 8 is transformed. d1~d8 is detail signal in scale of 1~8 and a8 is the approximate signal in scale of 8(Fig.5). The analysis of the experimental data indicates that the evoked

potential energy mainly concentrates on d5, d6 and d7. These frequency bands can reflect P_VEP main feature. P_VEP wave shape extracted by wavelet is shown in Fig.6.

After acquiring the complete P_VEP wave, P_VEP latency and amplitude are calculated to assist diagnosing amblyopia. At the same time, the best spatial stimulated frequency of visual system is obtained. Fig.6 is the spatial frequency threshold searching curve when the subject is examined on right eye and threshold is 30×24. The three curves separately indicate P100 wave latency, the peak amplitude and the peak amplitude/latency under different spatial frequency. When the spatial frequency is 30×24,

the performance of P_VEP is best, namely larger peak and shorter latency. So 30×24 is chosen as the patients’ best stimulated spatial frequency. The treatment is effective.

3. Conclusion

The goal in the treatment of amblyopia is to restore visual acuity in the affected eye and once this has been accomplished, to prevent recurrence of the disorder. The traditional treatment for amblyopia is occlusion of the dominant eye and forced use of the amblyopic eye [13-14]. In this paper, on the basis of the latest research about advanced amblyopia treatment, we put forward a new amblyopia treatment solution combined with P_VEP. We can provide the patients with personalized treatment through searching the best stimulated spatial frequency in
avoid of blindly choosing frequency. Under the best spatial frequency, the patients are easy to stimulate the visual system. Our method has good compliance and is more interesting and effective. In the future, the games using 3D technology will be using for treatment combined with binocular dichoptic.

References