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Near and distance stereopsis restoration in amblyopia with S3D computer treatment

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弱视患儿3D训练远近距离立体视恢复的疗效评价

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摘要

目的:评价使用立体3D技术作为一种视觉功能训练方法对弱视患儿的治疗效果。

方法:纳入30名儿童,年龄4~16y,其中18例是屈光不正性弱视(ametropic amblyopia,AMA),12例是屈光参差性弱视(anisometropic amblyopia,ANA)。双眼使用立体3D技术进行视觉功能训练,每次训练时间1h,每例患者训练约33次(平均:32±8)。在每次训练前后检查患者每眼的最佳矫正视力,使用同视机检查融合范围和远距离立体视,并使用颜氏随机点立体视图谱检查近距离立体视。

结果:在训练治疗后,所有弱视患儿最佳矫正视力较训练前均有显著提高,训练后融合范围较训练前显著扩大,尤其在屈光参差弱视患儿中融合范围扩大和立体视觉的恢复较屈光不正弱视患者组更明显。训练后近距离立体视觉的恢复程度要优于远距离立体视觉。

结论:立体3D视觉训练系统可以有效地恢复弱视儿童双眼立体视功能。

关键词:立体视觉;弱视;融合;屈光不正性弱视;屈光参差性弱视

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Abstract

• AIM: To evaluate the effect of stereoscopic 3D (S3D) technology as a visual training system in children with amblyopia.

• METHODS: Totally 30 children, aged 4-16 years old, 18 with ametropic amblyopia (AMA), and 12 with anisometropic amblyopia (ANA) were recruited in this study. A binocular 3D shutter glasses technology visual training system was used for training trials. Each training time lasted 1h, and the number of training trials totaled 33 (mean±SD: 32±8) times on average, per-person. Before and after each training trial, the best corrected visual acuity (BCVA) of each eye, range of fusion by synoptophore, as well as near and distance stereopsis acuity by Yan Shaoming random-dot test and synoptophore respectively was measured.

• RESULTS: A significant difference was found pre- and post treatment in BCVA in both kinds of amblyopia studied. Significant improvement was also found in fusion range and stereopsis acuity. The improvement of fusion range and stereopsis recovery could be seen in ANA than in AMA patients. The near stereopsis acuity recovery in ANA group might more easily to regain stereoacuity at near than in AMA group.

• CONCLUSION: S3D display vision training systems are indicated for the recovery of stereoacuity in children with amblyopia.

• KEYWORDS: stereopsis; amblyopia; fusion; ametropic amblyopia; anisometropic amblyopia

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INTRODUCTION

About 5-10% of the American population are totally stereo blind or have impaired stereovision, which means these people do not perceive depth as normal and the 3-dimensional structure of the natural world. Furthermore, they have heightened difficulty specific tasks, such as driving and playing badminton, and other cognitive activities requiring both speed and accuracy[1-2]. One of the main causes of stereo blindness is believed to be juvenile strabismus or amblyopia[3]. If not treated early enough, usually before 7 years of age, strabismus and amblyopia may deteriorate into a lack of stereopsis[4].

The common cause of amblyopia is anisometropia, which is a condition where one eye has a different refraction power in terms of magnitude from the other eye but the same error type[5]. In amblyopia, the brain switches off input from the "weaker" eye because of the conflicting or unequal input from both eyes. This is the main reason why amblyopia is combined with bad stereoacuity or stereo blindness, as has been described in various review articles[4].

There are lots of therapies for amblyopia with the binocular approaches gaining widespread attention lately[6-7]; Hess provides a brief review of related articles in 2015 and Thompson. Since the stereoscopic 3D (S3D) computer technology can give both eyes equal external input stimulus, it can strengthen or restore the normal binocular fusion.

There hasn't been a lot of studies that addresses the rehabilitation of stereoacuity at different distances, especially after the S3D stereo training in amblyopia[9-10]. The aim of our research was to evaluate the effect of S3D technology as a visual training system in children with amblyopia. Specifically, we measured the improvement of stereoacuity in both near and distance after both types of amblyopic patients regain their normal binocular visual acuity, BCVA by S3D treatment.

SUBJECTS AND METHODS

The procedures used conformed to the tenets of the Declaration of Helsinki. The Review Board and Ethics Committee of the Shenzhen Eye Hospital and the local Administration of the Shenzhen Aier Eye Hospital approved this study. Written informed consent was obtained from parents or guardians of all participants. The study was conducted at the Shenzhen Aier Eye Hospital in China.

A total of 30 subjects, aged 4-16 (mean: 10) y were recruited with 18 males and 12 females. Out of which 12 had anisometropic amblyopia (ANA) and 18 with ametropic amblyopia (AMA). We placed the subjects in these groups based on the criteria defined by the American Association for Pediatric Ophthalmology and Strabismus (AAPOS). The definition of ANA is that whenever the refractive error difference between the two eyes is greater than 1.00 D in an oblique axis also have induced at least two lines BCVA difference between the eyes[11]. All subjects wore their habitual glasses daily and were wearers for at least 6mo prior to the study. Furthermore, their refraction was checked and an updated prescription for a new pair of glasses provided if necessary. The corneal light reflex test, cover-uncover test and alternating cover test were used to measure ocular alignment. Detailed characteristics of the two different kinds of amblyopia are presented in Table 1.

We used a S3D desktop computer training system with the following specifications: ASUS VG278HE 27' Full HD 3D 1920×1080 refreshed 144Hz and running Windows 8.1 and NVidia 3D Vision 2 Wireless Glasses Kit (Expressway Santa Clara, CA, USA). The NVidia 3D Vision Photo Viewer Software, modified by Beijing Jiachengshixin Digital Medical Technology Co. was used to display 3D images (Figure 1A). The shutter glass lenses used in the study lighten and darken in synchrony with the monitor but faster than the user can perceive. Patients were made to sit on a comfortable chair 60 cm from the screen during the treatment while wearing the shutter glasses. Each treatment session contained different sets of trials, the number of training trials totaled 33 (mean±SD: 32±8) times on average. Participants were exposed to 4 trials/wk and the duration of each trial lasted 60min.

Each trial followed the program made by the Beijing Jiachengshixin Digital Medical Technology Company, which included three different sessions. The first session had to do with increasing the binocular visual acuity threshold. We used a two-down, one-up staircase procedure to measure single letter acuity and disparity threshold of both eyes. The second session consisted of the fusing enhancement training in which a target practice game with a figure fusion game were administered to the patients to enhance their fusion range, which we show a typical training picture (Figure 1B). The third session was the dynamic stereo vision training game, which challenged the patients to find a way to fuse two separate random dots images into one (Figure 1C). Each game had feedback scores that automatically advances the level for the next game after which BCVA and stereoacuity were measured. A crowded Chinese Tumbling "E" chart (GB11533-2011, Shijia Company, Guangzhou, China) was used at a distance of 5 m for the BCVA measurement. Visual acuity was defined as the LogMAR associated with 75% correct identification. All patients underwent slit lamp (hand-held or chair unit) examination by a pediatric ophthalmologist. Yan shaoming's stereoscopic random-dot test charts[12] (People's Medical Publication House, Version III) was used for near stereo acuity (40 cm) and synoptophore

Table 1 Characteristics of children with AMA or ANA in the study

Observer No.	Sex	Age(y)	Treatment history	Eye	Correction	Diagnosis	Acuity(LogMAR)
1	M	12	Glasses for 6mo, no patching	AE(R)	+1.25DS/−4.00DC×5	AMA	0.22
				DE(L)	+0.75DS/−2.75DC×180		0.22
2	F	7	Glasses for 16 mo, patching 2h/d	AE(R)	+2.50DS/−2.50DC×180	ANA	0.22
				DE(L)	+0.25DS/−0.50DC×10		0
3	M	5	Glasses for 9mo, no patching	AE(R)	+4.75DS/−2.50DC×20	AMA	0.4
				DE(L)	+4.00DS/−3.00DC×177		0.4
4	F	8	Glasses for 13mo, patching 5:2	AE(R)	+2.75DS/−2.25DC×35	ANA	0.22
				DE(L)	PL		0
5	M	7	Glasses for 19mo, patching 2h/d	AE(L)	+7.75DS/−2.00DC×20	ANA	0.22
				DE(R)	+6.00DS/−1.75DC×165		0.10
6	F	6	Glasses for 12mo, patching 2h/d	AE(L)	+4.50DS/−3.00DC×10	AMA	0.30
				DE(R)	+4.00DS/−3.00DC×165		0.22
7	M	7	Glasses for 15mo, patching 4h/d	AE(R)	+5.75DS/−0.25DC×170	ANA	0.30
				DE(L)	+1.50DS		0.10
8	F	6	Glasses for 14mo, no patching	AE(R)	+5.50DS/−1.00DC×10	AMA	0.22
				DE(L)	+5.75DS/−1.00DC×180		0.22
9	F	6	Glasses for 24mo, patching 2h/d	AE(R)	+6.75DS/−0.50DC×180	AMA	0.30
				DE(L)	+7.00DS/−0.50DC×180		0.22
10	F	8	Glasses for 15mo, no patching	AE(L)	+4.00DS/−1.50DC×170	ANA	0.22
				DE(R)	+1.50DS/−0.50DC×175		0
11	M	5	Glasses for 14mo, no patching	AE(R)	+6.50DS/−3.00DC×180	AMA	0.30
				DE(L)	+5.00DS/−3.25DC×180		0.30
12	F	6	Glasses for 10mo, no patching	AE(R)	+1.75DS/−3.25DC×170	AMA	0.22
				DE(L)	+2.00DS/−3.25DC×10		0.22
13	M	9	Glasses for 9mo, no patching	AE(L)	+8.50DS/−1.25DC×40	ANA	0.40
				DE(R)	+6.75DS/−0.75DC×130		0
14	M	6	Glasses for19mo, no patching	AE(R)	+5.00DS/−1.50DC×5	AMA	0.30
				DE(L)	+4.50DS/−1.00DC×180		0.30
15	M	4	Glasses for 15mo, no patching	AE(R)	−1.75DS/+4.00DC×100	AMA	0.30
				DE(L)	−1.50DS/+4.00DC×100		0.30
16	M	7	Glasses for 17mo, patching 2h/d	AE(R)	+0.75DS/−2.00DC×180	AMA	0.40
				DE(L)	+0.50DS/−1.50DC×180		0.30
17	M	13	Glasses for 84mo, no patching	AE(R)	+8.00DS/−0.50DC×165	AMA	0.30
				DE(L)	+8.25DS/−0.50DC×180		0.30
18	F	6	Glasses for 7mo, patching 2h/d	AE(L)	+1.00DS/−2.00DC×175	AMA	0.40
				DE(R)	+1.50DS/−2.00DC×170		0.22
19	F	16	Glasses for 6mo, no patching	AE(R)	+14.75DS/−1.25DC×180	AMA	0.40
				DE(L)	+14.50DS/−1.00DC×170		0.40
20	M	9	Glasses for 48mo, patching 4h/d	AE(L)	+11.50DS/−2.25DC×165	ANA	0.40
				DE(R)	+9.50DS/−2.00DC×10		0.22
21	M	11	Glasses for 30mo, patching 5:2	AE(L)	+3.25DS	ANA	0.40
				DE(R)	PL		0
22	M	6	Glasses for 12mo, no patching	AE(R)	+4.00DS/−4.50DC×5	AMA	0.15
				DE(L)	+3.00DS/−4.25DC×170		0.10
23	M	6	Glasses for 12mo, no patching	AE(L)	−1.25DS/+4.25DC×92	AMA	0.30
				DE(R)	−0.75DS/+3.50DC×87		0.22
24	M	7	Glasses for 31mo, no patching	AE(R)	+1.75DS/−2.25DC×170	AMA	0.22
				DE(L)	+1.50DS/−2.00DC×180		0.22
25	M	10	Glasses for 72mo, no patching	AE(L)	+9.75DS/−0.50DC×175	ANA	0.22
				DE(R)	+7.75DS/−0.50DC×180		0.10
26	F	12	Glasses for 36mo, patching 6h/day	AE(L)	+2.50DS/−0.50DC×165	ANA	0.30
				DE(R)	−1.00DS		0
27	M	6	Glasses for 29mo, patching 5:2	AE(L)	+8.25DS/−0.75DC×35	ANA	0.30
				DE(R)	+1.25DS		0
28	F	7	Glasses for 26mo, no patching	AE(L)	+2.75DS/+2.50DC×90	ANA	0.22
				DE(R)	+1.25DC×90		0
29	M	4	Glasses for 9mo, no patching	AE(R)	+3.00DS/−2.25DC×175	AMA	0.22
				DE(L)	+3.00DS/−3.00DC×170		0.22
30	F	15	Glasses for 36mo, no patching	AE(L)	−2.75DS/−0.50DC×150	AMA	0.22
				DE(R)	−3.50DS/−0.50DC×10		0.15

M: Male; F: Female; AE: Amblyopia eye; DE: Dominant eye; AMA: Ametropic amblyopia; ANA: Anisometropic amblyopia.

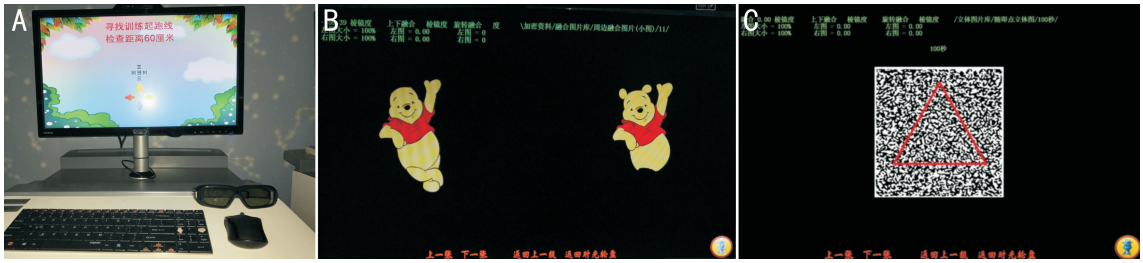

Figure 1　S3D desktop computer training system　A: S3D desktop (ASUS VG278HE) equipped with Nvidia 3D Vision 2 Wireless Glasses Kit (Expressway Santa Clara, CA, USA); B: Fusion practice procession; C: Stereoacuity practice procession.

Table 2　Wilcoxon test for pre-training and post-training data by two groups

Groups	N	Pre-training		Post-training		Z	P
		P_{50}	$P_{75}-P_{25}$	P_{50}	$P_{75}-P_{25}$		
AMA	18	0.6	0.10	1.0	0.00	171	<0.001
ANA	12	0.6	0.10	1.0	0.05	78	<0.001
Z	–	112.5		88.5		–	–
P	–	0.8544		0.3007		–	–

AMA: Ametropic amblyopia; ANA: Anisometropic amblyopia; N: Number.

(Type: TSJ-IV, Changchun City Photoelectric Devices Co, Ltd., China) used for distance (5 m) stereo acuity[13] during the pre- and post-treatment phase. The range of convergence and divergence was also measured by synoptophore before and after the treatment. We classified the degree of stereopsis into different scores as: good (≤ 60 arc sec, score 4), moderate (> 60, ≤200 arc sec, score 3), poor (>200, ≤800 arc sec, score 2), worse (>800, ≤1600 arc sec, score 1) and nil (>1600 arc sec, score 0).

Statistical analyses were performed using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA). We useda rank-sum test to compare the pre- and post-visual training BCVA, near and distance stereo acuity, and the range of binocular convergence and divergence within and between subjects.

RESULTS

The BCVA pre- and post treatment showed out a significantly improvement in Table 2. The median value (P_{50}) of BCVA for these 30 patients pre - training was 0.6, and the interquartile range ($P_{75}-P_{25}$) was 0.10, while as the median value (P_{50}) of BCVA after training was 1.0, and there was a statistic significant difference by using the paired Wilcox test ($Z=465$, $P<0.001$). But there was no significant difference between the AMA and ANA groups(Table 2).

Yan's stereo random dot test chart for near distance as shown in Figure 2. Stereopsis improvement could be seen in Yan's stereo random dot test chart in both kinds of amblyopia. The stereoacuity classified score of per-treatment in AMA group and ANA group are presented as mean±SD, which were 2.09±1.78 and 0.89±1.36 respectively, while the value of post-treatment of these two groups were 3.67±0.48 and 3.56±0.53 respectively.

There was a significant stereoacuity improvement in near distance after the treatment in both kinds of amblyopia ($P<0.01$). There was a larger improvement in the ANA group (shows in yellow arrow) than the AMA group (shows in blue arrow) as shown in Figure 2.

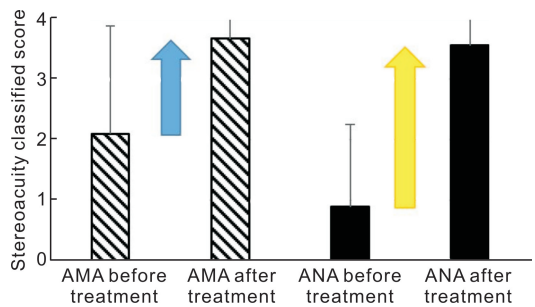

Figure 2　The stereoacuity pre and post the treatment by Yan's chart in near distance　AMA: Ametropic amblyopia; ANA: Anisometropic amblyopia.

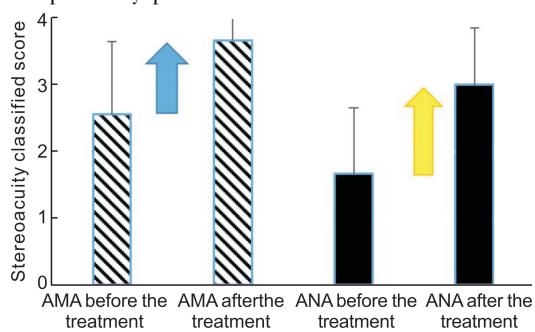

Figure 3　The stereoacuity pre- and post- the treatment by synoptophore in far distance　AMA: Ametropic amblyopia; ANA: Anisometropic amblyopia.

The far distance stereoacuity of pre- and post-treatment were checked by synoptophore, and the stereoacuity classified score values were shown in Figure 3, which presented as mean±SD in AMA group and ANA group of pre treatment were 2.56±1.09 and 1.67±0.98 respectively, while the value of post-treatment of these two groups were 3.67±0.68 and 3.00±0.85 respectively. There was a significant stereoacuity improvement in far distance after the treatment in both kinds of amblyopia ($P<0.01$). The ANA group had a larger stereoacuity regain scale (shows in yellow arrow) than the AMA group (shows in blue arrow).

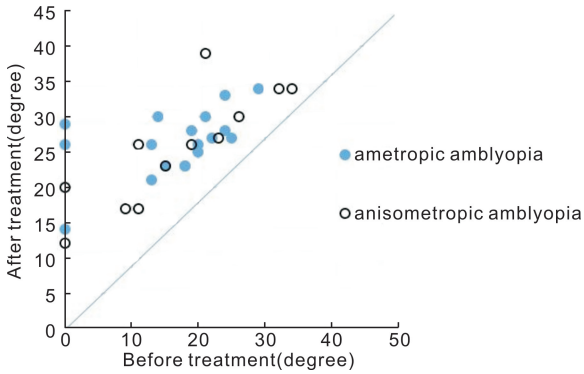

Figure 4 The range of fusion before and after the treatment.

We checked the range of fusion value pre- and post-treatment in AMA group presented as mean±SD were 16.39±8.66 and 26.28±4.60, while in ANA group were 16.75±11.15 and 25.42±8.05, the enhanced range in AMA and ANA groups were 9.89±4.07 and 8.67±3.10, which could be clearly seen the improvement in the Figure 4 ($P<0.01$). But there had no significant difference of the enhanced range value between the two amblyopia groups ($P>0.50$).

DISCUSSION

The results show a significant recovery of stereoacuity in both far and near distances. Hess *et al*[14] has already shown evidence for the recovery of binocular vision in amblyopia using dichoptic motion stimulus in an iPad. However, their study did not show if the recovery of stereopsis was at different distances. This could be due to the fact that there are few accurate stereoacuity measurements for far distance. In this study, we used the synoptophore as the distance stereoacuity detector, which is unlike the AO Vectographic Project-O-Chart Slide test and Mentro II-SG B-VAT (Baylor Video Acuity Test - Mentor system 2) that uses special spectacles[15-16]. We believe our system performs better than the other prior used techniques since we can measure fusion range during the same measurement time of testing. Some studies use it to detect the early stages of intermittent exotropia, to evaluate the proper time for an operation[17].

The study shows that the stereoacuity scale before training in ANA group is lower than AMA group in both far and near distances, and the regain scale of the stereoacuity after training is also larger in ANA group than in AMA group in both distances, which demonstrate that the stereoacuity regain pattern might different in different amblyopic groups. ANA patients might more easily to regain stereoacuity at near than AMA group. This is partly in agreement with a study of intermittent extropia that showed these patients first lose their stereopsis at distance and may regain this function at near distance soon after surgery[18]. This phenomenon is more like our ANA patients in our study, which addresses our hypothesis that monovision patients might easer regain their stereoacuity at near distance more than at far after treatment.

Previous studies showed ANA patients have more severe stereoacuity loss than AMA patients, which is also shown in our data[19-20]. The main reason for the poor stereo acuity in ANA is because of selective binocular deprivation that affects neural mechanisms underlying binocular summation[20].

Some patients in the study were initially stereoblind but showed total recovery of stereopsis at the end of the treatment and were able to enjoy stereopsis 3D movies in theater for the first time. This fantastic binocular treatment approach result has been firstly mentioned by Hess's study in 2011[10], in which they provided a new computer binocular game to treat the suppression of the strabismus amblyopia, and found out the enhancement of stereoacuity after the monocular suppression had been resolved. This result did not agree with the Kelly *et al*[21] binocular computer game study, which indicated no significant improvement in stereoacuity. This might be because the binocular treating game used in that study did not focus on enhancing the range of binocular fusion. Further studies are needed to confirm this result.

Parents of subjects in this study also stated that reading and writing habits in this subjects lasts longer than pre-treatment. This phenomenon might not only due to the recovery of the stereopsis but also the larger range of the convergence regained after the treatment. Some studies conducted on the relationship of convergence capacity with the chronic fatigue syndrome (CFS)[22], showed that smaller convergence ranges appear in these patients but made their eyes fatigued and hard to maintain focus for long during near distance. Our result also assumes that people with CFS might benefit from this binocular training because of the fusion range enlargement.

There are some limits of our treatment. One is about the training trials, each took 60min, and the whole session include 14 to 50 trails, which sometime was hard for the patients to cooperate and endure. Another is with the game contents which could not change in every trial and made patients bored.

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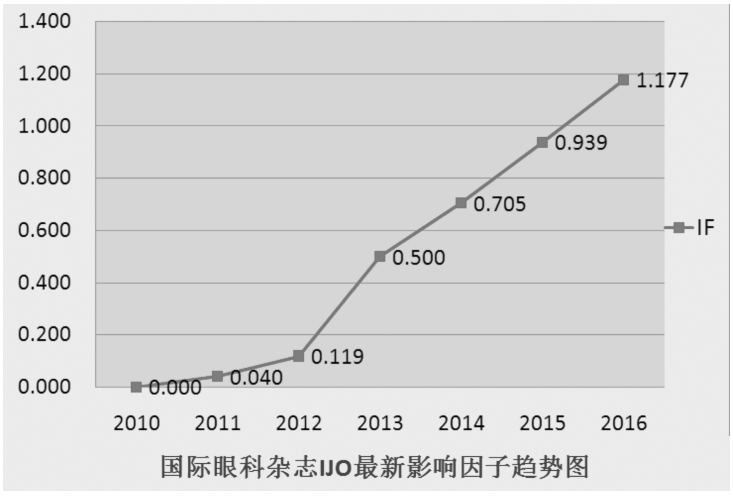
热烈祝贺 IJO 最新影响因子达到 1.177

2016 年 SCI JCR 影响因子正式出炉,《国际眼科杂志》英文刊 IJO 最新影响因子为 1.177,趋势图如下:



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