Influence of RDS Size and Density on Stereopsis in Curative Amblyopic Children

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Abstract: Objective: To evaluate the effects of different spacing visual acuity (VA) charts on VA in curative amblyopic children as well as the effects of random-dot size and density on stereopsis using a stereopsis test system based on computer. **Methods**: This was a two-part study conducted in a referral practice. The subjects were 113 curative amblyopic children. (1) Single visual target, 1/4-time-, 1/2-time-, 1-time- and 2-time-spacing crowding VA charts were used respectively to examine the VA of each subject, and then the difference of VA among the five groups was analyzed. (2) A stereopsis test system based on computer was applied to examine stereopsis for 113 curative amblyopic children using random-dot stereogram (RDS) with four different sizes and three different densities of random-dots, respectively, and then the difference of stereopsis among the groups of different sizes and densities of random-dots. **Results**: (1) The average VAs of amblyopic children examined by single visual target, 1/4-time-, 1/2-time-, 1-time- and 2-time-spacing VA charts were (0.583±0.042), (0.412±0.033), (0.469±0.033), (0.523±0.041) and (0.562±0.039). Pairing comparison showed there were statistically significant differences among the five groups ($P < 0.05$, except P between the single visual target group and the 2-timespacing group which was 0.079, the range of P value was 0.000~0.079). (2) There were no statistically significant differences among the different densities of random-dots when the size was constant ($P > 0.05$, the range of P value was 0.102~0.879). Also there were no statistically significant differences among the different sizes of random-dots when the density was constant ($P > 0.10$, the range of P value was 0.152~1.0). **Conclusions**: The crowding phenomenon still existed in curative amblyopic children. But the crowding phenomenon did not affect random-dot stereopsis test. It suggests that the mechanism of extracting RDS visual parallax information is different from the visual identification mechanism of fine visual targets.

[Qiang Wang, Jin Xu, Zhenguo Chen. **Influence of RDS Size and Density on Stereopsis in Curative Amblyopic Children.** *Life Sci J* 2013;10(3):1094-1098] (ISSN:1097-8135). http://www.lifesciencesite.com. 159

Keywords: Amblyopia; stereopsis; visual acuity; crowding phenomenon

1. Introduction

Stereopsis is an important component of binocular vision and stereoacuity test is subjected to the impact of the texture of the stereogram used. (Fawcett 2005) The study by Simons et al. showed that the time and acuity for subjects to identify different stereograms are affected by different textures of the stereograms, and texture included the shape, size, complexity and other aspects of depth graphs. However, up to now, there are diverse random-dot stereograms with varying densities, sizes and shapes of random-dot, so the examination results are also incomparable. (Simons 1981). The computerized random-dot stereogram (RDS) developed by Xu Jin et al. can be used in examination by adjusting the density, size and shape of the random-dot.(Xu et al.,2006) Amblyopic children has a charecters of reading difficulties, while the existing andom-dot stereograms fail to take this factor into account.(Walraven and Janzen 1993). The first part of the study was to checked whether the curative amblyopic children had crowding phenomenon by analyzing different VA charts; the second part was to examined the stereopsis in the amblyopic children by adjusting the density, size and shape of the random-dot to analyze RDS effect on the stereopsis in curative amblyopic children. It was reported now as follows.

2. Subjects and Methods

2.1 General data

Totally 113 amblyopic children were assigned to this study, including 55 males and 58 females, aged 4-10years (mean: 6.3 ± 2.1 years). All the patients went to the hospital due to poor vision, and had been given glasses or amblyopia training for 12 ± 3 months after the diagnosis with bilateral amblyopia or unilateral amblyopia. Inclusion criteria as followed: amblyopic children aged from 4 to 10 years with stereoacuity ≤400" and anisometropia <1.0D, without color weakness color blindness, dominant and <5$^{\triangle}$ recessive strabismus. Who all children met the above criteria have received the computerized stereopsis check system training for two weeks.

2.2 Instruments and equipment

2.2.1 The study employed 5 types of VA charts with different visual target spaces, all VA charts derived from the standard logarithmic VA chart for self-test, in which 1/4-time-spacing crowding VA chart, 1/2-time-spacing crowding VA chart, 1-time-spacing crowding VA chart and 2-time-spacing crowding VA chart were shown in Figure 1.

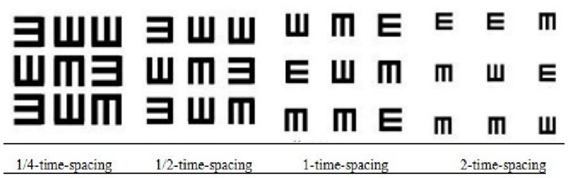

Figure 1. 1/4-time-spacing, 1/2-time-spacing, 1-time-spacing, and 2-time-spacing crowding VA charts

2.2.2 (1) S-L801 luminance(Jiangsu Yangzhong Photoelectric Instrument Factory) meter was used, the average screen brightness was 156cd/m^2. The brightness in front of the eyes of subjects was 26.7 cd/m^2 on average behind green-free barrier filter and 28.4 cd/m^2 behind red-free barrier filter. TNO red-green sub-visual spectacles were applied. (2) The computerized random-dot stereogram (RDS) developed by Xu Jin et al. was employed [3].

2.3 Examination method

2.3.1 In the same examination room,under standard lighting and optimal refraction correction conditions, with a Hewlett-Packard computer with display model HPL1506, average brightness of 80.0LUX and resolution of 800 * 600, the left and right eye VAs of each subject were examined one by one by using 99.8%-contrast single visual target VA chart, 1/4-time-spacing crowding VA chart, 1/2-time-spacing crowding VA chart, 1-time-spacing crowding VA chart and 2-time-spacing crowding VA chart, respectively, and the best corrected visual acuity of subjects in each group was measured. In VA examination, a VA chart with larger visual targets was firstly used to demonstrate subjects the examination method—the visual targets' direction was pointed out following the indicating bar outside the frame. The VA of examination glasses was gradually increased and the subjects were encouraged to try their best to recognize the visual targets' direction. Guessing was allowed, but each visual target must be recognized. If more than half of visual targets in a line were seen, it would be considered that the subject could see all the visual targets in that line; if not, the VA obtained from last line would be recorded. The VA obtained from each spacing VA chart was recorded.

2.3.2 TNO red-green sub-visual spectacles for the two eyes. The right eye wore green glass, while the left eye wore red glass. Stereoacuity was examined in a semi-dark room, at 85cm from computer screen and the eyes were at the same level as the computer screen. Each subject was randomly subject to RDS stereoacuity examination by 4 different sizes and 3 different densities. In the examination, when the distance was 85 cm, stereoacuity was (dot pitch 2 – dot pitch 1) * 60 seconds. The dot pitch was adjusted during examination, subjects would pass if they could correctly recognize 4 depth graphs at least twice (consecutively) and the minimum parallax of such subjects was recorded. The examination of all subjects was completed by the same examiner. Parameter settings of the RDS were shown in Table 1.

Table 1. Parameter settings of RDS

Parameter	Set value
Resolution	1024*768=786432
Dot texture	Square
Depth graph	Round graph with notches facing up, down, left and right respectively
Dot size	
1	Number of dots on the screen: 349535, 196680 and 87381
2	Number of dots on the screen: 87381, 49152, and 21845
3	Number of dots on the screen: 38836, 21845 and 9709
4	Number of dots on the screen: 21845, 12288 and 5461

Note: Number of dots on the screen was the density.

2.4 Statistical methods

SPSS 11.5 software package was used for mean description ($\bar{x}$±s) and pair-wise comparison of different spacing VA chart groups. The examination results from random-dot stereograms with varying sizes and densities were subject to ANOVA and multiple comparisons. $P < 0.05$ represented a statistically significant difference.

3. Results

3.1 The examination results of amblyopic children by different spacing VA charts and the pair-wise comparison results were shown in Table 2. That the average VA of amblyopic children examined by different spacing VA charts were 0.583±0.042, 0.412±0.033, 0.469±0.033, 0.523±0.041 and 0.562±0.039., respectively;the pair-wise comparison showed that there was a statistically difference between all groups(P <0.05 among all the 5 different spacing VA chart groups; P was 0.000~0.079, except that P between single visual target group and 2-time-spacing group was 0.079).

Table 2. VA examination results of amblyopic children by different spacing VA charts ($\bar{x}$ ±s)and pair-wise comparison (P)

		1	2	3	4	5
1	0.583±0.042		0.000	0.000	0.005	0.079
2	0.412±0.033			0.007	0.000	0.000
3	0.469±0.033				0.008	0.000
4	0.523±0.041					0.044
5	0.562±0.039					

Note: 1/2/3/4/5 respectively represented single visual target, 1/4-time-, 1/2-time-., 1-time- and 2-time-spacing crowding VA chart groups, and the values in the brackets represented VA mean ± standard deviation.

3.2 Means and ANOVA results of random-dots with different densities but a fixed size were shown in Table 3. It could be found from Table 3, one-way ANOVA showed that the 3 different densities had no statistically difference (P>0.05). The effects of random-dots with different densities but a fixed size on the stereoacuity of children had no statistically difference (P>0.05) (Table 4). As shown in Table 5, the effects of random-dots with 4 different sizes but the same density on the stereoacuity of children had no statistically difference (Table 5. P>0.05).

Table 3. Mean and ANOVA of random-dots with 3 different densities but a fixed size

point size	**mean**±SD	**ANOVA**
1	118.4.0±79.8	F=2.574, P=0.079
2	93.6±48.4	F=0.746, P=0.428
3	111.1±89.2	F=0.874, P=0.485
4	125.8±101.9	F=0.658, P=0.524

Table 4. Multiple comparisons of random-dots with different densities on the stereoacuity in amblyopic children (P)

density of points	Point size			
	1	2	3	4
A vs B	0.302	0.879	0.154	0.524
A vs C	0.185	0.421	0.425	0.102
B vs C	0.689	0.385	0.504	0.274

Note: 1/2/3/4 represented dots with different sizes, and A/B/C represented different densities, in which A represented the minimum density, B represented the moderate density, and C represented the maximum density; A vs B represented the comparison between density A and density B when random dot was fixed at size 1, and the rest could be thus deduced similarly.

Table 5. Multiple comparisons of random-dots with different sizes on the stereoacuity in amblyopic children (P)

Point size	density of points		
	A	B	C
1 vs 2	0.152	0.845	0.395
1 vs 3	0.241	0.204	0.847
1 vs 4	0.405	0.857	0.455
2 vs 3	0.784	0.271	0.684
2 vs 4	0.547	0.914	1.000
3 vs 4	0.745	0.198	0.547

Note: 1/2/3/4 represented dots with different sizes, and A/B/C represented different densities, in which A represented the minimum density, B represented the moderate density, and C represented the maximum density; A vs B represented the comparison between density A and density B when random dot was fixed at size 1, and the rest could be thus deduced similarly.

4. Discussion

Amblyopia is a common disease in visual development of children. Photostimulation into the eyes is insufficient, the chance for reflection of objects projected on the macula lutea is deprived and/or clear objective image deriving from unequal visual inputs can produce conflicts with unclear objective image, all which reject normal development of visual performance and result in monocular or binocular visual deterioration.(Mai 1997) Amblyopia ,which can damage the visual functions of children include VA decrease and stereopsis. In the treatment of amblyopia, it tends to attach importance to the improvement of VA. However, it is very important to establish and restore visual functions included normal corrected binocular VA, simultaneous vision and fusion, and stereopsis. (Li 2004)

Stereopsis is an important component of binocular vision, and it is a great value for the judgment of strabismus, amblyopia, binocular vision and treatment effect as well as the screening of patients with strabismus or amblyopia. Especially for young children whose simultaneous vision and fusion cannot be examined, stereopsis inspection is almost the only feasible method to judge binocular vision.(Schmidt 1994) Zhang Wei et al. (2004) once observed that the neuroelectricity physiological reaction time to three-dimensional stimulation in children aged 5 to 8 years was longer than adults, so we speculate that the stereoscopic vision of children at this age do not yet become mature to the adult level. The neuroelectricity physiological reaction time in children aged 9 to 12 years was close to adults, suggesting that the maturity of stereoscopic vision development for children was about 9 to 12 years of age.. All children treated during the sensitive period had the opportunity to acquire stereopsis. Wang Kunming et al.(2006) proposed that after the VA recovered to normal, only about two thirds of curative amblyopic children acquired far stereopsis, while about one third acquired near stereopsis.

Amblyopic children are characterized by separation difficulty. Amblyopic separation difficulty, also known as crowding phenomenon, is considered as an unusual spatial interaction, and the masking effect of the adjacent object outlines (such as stripes or letters) on the target letter, making it hard to recognize the targ(2005) believed that normal children below the age of 8 years had crowding phenomenon, which was more pronounced and prolonged to an elder age in amblyopic children, yet rapidly disappeared in normal children after the age of 10 years. The study by Leat et al.(1999) proved that crowding phenomenon still existed in amblyopic adults. Wang Guangji et al. also pointed out: ① VA checked by single visual target could reflect the real potential function of the eye, while in the judgment of treatment effect on amblyopia, the VA tested by parallel visual targets was more important; ② The standard for VA recovery of amblyopic patients included normalization of single visual-target VA and parallel visual-target VA, and the difference between these two VAs reached the level of children at the same age.(Wang 2005) This study employed standard logarithmic VA charts with different spaces in the examination of curative amblyopic children, and the results showed that amblyopic children still had separation difficulty despite of VA improvement, and the larger the visual target spacing was, the better the VA of amblyopic children would be. The existing RDSs fail to take this factor into account, and the current stereopsis studies in children with amblyopia have rarely designed this factor.

In this study, a novel stereopsis test system based on computer developed by Xu et al. is employed to examine the stereopsis of low-VA subjects. This system enabled the random adjustment of the size, density, shape, brightness and other parameters of random-dot for stereopsis inspection, which is suitable for scientific research.(Sun et al.,2004) The study by Sun Weifeng et al. showed that the perception of static RDS required a certain amount of information—the random-dot density must exceed a certain threshold.(Wang 2005) The random-dot density designed in this study exceeded the amount of information required by static RDS, so it is suitable for scientific research. In this study, RDS was used to examine the stereoacuity in 113 amblyopic children whose VA had recovered to normal after training. The results showed that the effects of random-dots with different densities but a fixed size on the stereoacuity of children had no statistically difference ($P>0.05$); the effects of random-dots with different sizes but the same density on the stereoacuity of children also had no statistically difference ($P>0.05$). In this study, a dot size of 1 pixel and a space of 1 were already beyond the recognition ability of VA, and could produce crowding phenomenon, but did not affect stereopsis, suggesting that the mechanism of extracting RDS visual parallax information does not require clear identification of random dots.

In summary, this study show that amblyopic children still had crowding phenomenon, but crowding phenomenon do not affect RDS stereoacuity examination, suggesting that the mechanism of extracting RDS visual parallax information is different from the visual identification mechanism of fine visual targets.

This work was supported by Project Y20080132 funded of Wenzhou Science & Technology and Bureau Agency Project funded of Heilongjiang Provincial Health Bureau (2005-185).

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8/4/2013