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Novel visual acuity charts providing high accuracy of measurements in children

Introduction: The purpose of our investigation was to evaluate the prospects for the novel visual acuity charts elaborated at the IITP RAS. In these charts, based on recent theoretical and experimental data, we used modified 3-bar targets (M3B) as the optotypes and placed them inside background pictures for better functioning of accommodation and oculomotor systems in the course of measurements. We called such structure of the charts as “inclusion design”.
Methods: The accuracy and reliability of visual acuity measurements with our novel charts were assessed in two groups of school children – with and without ophthalmopathology (GP and GN). For detailed analysis, the groups GN (N=65) and GP (N=65) were divided on younger (7-12 yr.) and older (13-18 yr.) subgroups: YGN (N=31) and OGN (N=34); YGP (N=32) and OGP (N=33). For comparison, in all these children, we also performed measurements by means of standard tumbling E optotypes embedded into the same charts. Thus, each patient was examined with M3B and E optotypes in test and retest sessions. Before measurements, all children were refracted and given proper optical correction. Examination was conducted both in monocular and binocular viewing conditions.
Results: Inclusion design of the charts provided convenience and noticeable acceleration of the measurements in comparison with commonly used designs. In both groups of children, the results revealed significantly better test-retest reliability with our novel optotypes – M3B – than with tumbling E. The mean test-retest values of binocular visual acuity in the subgroups appeared to be: 1.36-1.36 (M3B) and 1.38-1.41 (E) in YGN; 1.60-1.62 (M3B) and 1.62-1.7 (E) in OGN; 0.65-0.65 (M3B) and 0.59-0.64 (E) in YGP; 0.68-0.68 (M3B) and 0.62-0.70 (E) in OGP. Monocular data demonstrated similar relationship. SDs for the values of individual test-retest differences were essentially less in the case of the novel optotypes. The average values of the test-retest differences demonstrated effect of learning for tumbling E but not for M3B.
Conclusion: Our novel visual acuity test charts based on modified 3-bar stimuli and having inclusion design seems to be promising for regular examining children and monitoring.

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1 Introduction

Purpose

The purpose of our investigation was to evaluate the prospects for the novel visual acuity charts elaborated at the IITP RAS. Proceeding from the recent theoretical and experimental data, we have used modified 3-bar targets (M3B) as the optotypes and developed an ingenious design for the charts – "inclusion design".

Acuity Charts

General structure of the charts proposed for measuring visual acuity (VA) in children is shown in Fig. 1. These charts contain novel optotypes and have specific structure.

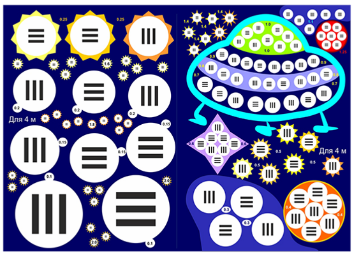


Fig. 1. The examples of novel visual acuity charts.

Optotypes

The optotypes for our charts were developed taking into account a set of criteria for providing accurate and reproducible VA measurements. Though nowadays many various optotypes are used in the VA charts for children – pictures, letters, tumbling E, Landolt C, Lea symbols, etc. – none of them can be considered as ideal for VA measuring aimed at monitoring and early diagnostics since all these optotypes do not allow to separate resolution acuity from recognition acuity. Unfortunately, recognition acuity is influenced by many factors beside visual capabilities, e.g. literacy, learning and IQ-index. Therefore, it is reasonable to base ophthalmic monitoring and early diagnostics on resolution VA.

The main idea of measuring resolution VA is to determine the highest recognizable spatial frequency (SF). The ideal stimuli for measuring resolution VA are sine wave gratings or Gabor patches widely used in scientific research. Each grating can be characterized by a single parameter – its SF. However, it is problematic to employ such stimuli in the manufactured VA charts since they need high quality printing and imply relatively large sizes. Most other optotypes are complex figures that have rich Fourier spectra containing a lot of low SF in addition to high SF. Though it is supposed that VA correspond to the highest SF in the stimulus spectrum, recognition of complex stimuli can be based on low SF as well: the presence of low SF provides a number of indirect cues (asymmetry, shape or orientation of blurred image, etc.) for recognition.

The optotypes used in the IITP charts represent a compromise between gratings and complex figures. These optotypes are versions of the well known 3-bar targets modified in such a way that only high SF could be used to recognize their orientation (horizontal vs vertical).

The essence of modification is illustrated by Fig. 2 showing both standard and modified 3-bar stimuli and their spectra. In addition corresponding data are shown for tumbling-E.

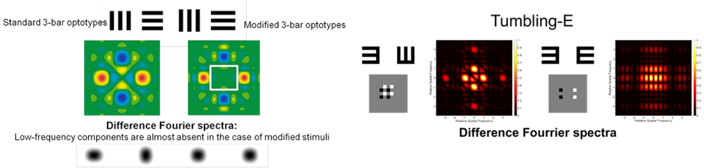


Fig. 2.

Chart design

In traditional VA charts, the optotypes are usually distributed over a uniform white background forming the lines of symbols with either regular or proportional spacing. These types of designs have certain advantages and disadvantages and, in total, seem to be more convenient for the optometrist than for the patient.

In the IITP charts, our optotypes providing an accurate VA measurements are put inside large and well recognizable background pictures.

Such a design (Fig. 1) has several advantages. It provides:

- Effective accommodation stimuli;
- Comfortable conditions for oculomotor system (gaze dynamics);
- Attention- attractive appearance;
- Possibility of combining high accuracy (viewing of the smallest optotypes) with high interest to the surrounding pictures;
- Possibility of producing a lot of the chart versions adapted to patient age and visual capabilities.

2 Methods

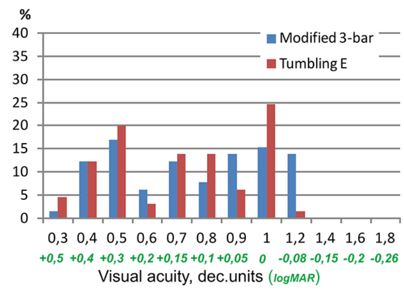
The accuracy and reliability of visual acuity measurements with our novel charts were assessed in two groups of school children – with and without ophthalmopathology (GP and GN). For detailed analysis, the groups GN (N=65) and GP (N=65) were divided on younger (7-12 yr.) and older (13-18 yr.) subgroups: YGN (N=31) and OGN (N=34); YGP (N=32) and OGP (N=33). For comparison, in all these children, we also performed measurements by means of standard tumbling E optotypes embedded into the same charts. Thus, each patient was examined with M3B and E optotypes in test and retest sessions. Before measurements, all children were refracted and given proper optical correction. Examination was conducted both in monocular and binocular viewing conditions.

3 Results

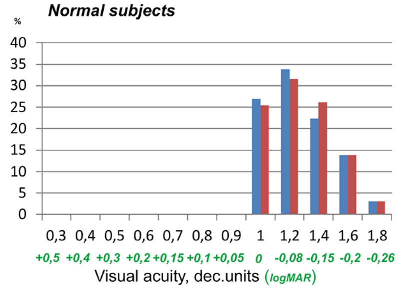
Inclusion design of the charts provided convenience and noticeable acceleration of the measurements in comparison with commonly used designs. In both groups of children, the results revealed significantly better test-retest reliability with our novel optotypes – M3B – than with tumbling E. The mean test-retest values of binocular visual acuity in the subgroups appeared to be: 1.36-1.36 (M3B) and 1.38-1.41 (E) in YGN; 1.60-1.62 (M3B) and 1.62-1.7 (E) in OGN; 0.65-0.65 (M3B) and 0.59-0.64 (E) in YGP; 0.68-0.68 (M3B) and 0.62-0.70 (E) in OGP. Monocular data demonstrated similar relationship. SDs for the values of individual test-retest differences were essentially less in the case of the novel optotypes. The average values of the test-retest differences demonstrated effect of learning for tumbling E but not for M3B.

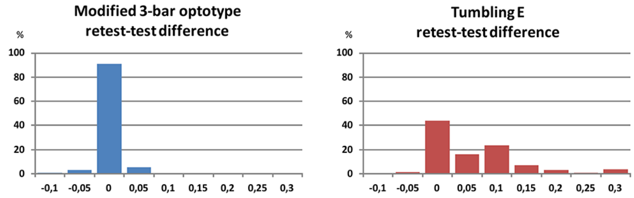
Groups of patients		Condition of assessment	Mean ±SD, Test: Modified 3-bar optotypes	Mean ±SD, Test: Tumbling E
Normal	Younger group	Monocular	1,16±0,20	1,18±0,20
		Binocular	1,36±0,24	1,38±0,25
	Older group	Monocular	1,36±0,20	1,37±0,20
		Binocular	1,60±0,25	1,60±0,22
Ophthalmo pathology	Younger group	Monocular	0,65±0,26	0,59±0,24
		Binocular	0,78±0,24	0,71±0,22
	Older group	Monocular	0,68±0,29	0,62±0,27
		Binocular	0,81±0,29	0,74±0,26

Patients with ophthalmopathology

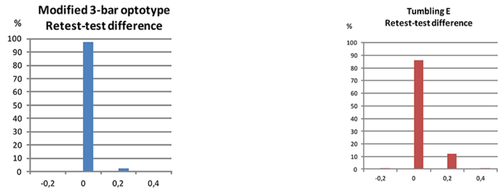


Normal subjects





The histograms of the differences "retest-test" for all children with ophthalmopathology



The histograms of the differences "retest-test" for all normal subjects

4 Conclusions

Our novel visual acuity test charts based on modified 3-bar stimuli and having inclusion design seem to be promising for regular examining children and monitoring vision.

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