Which psychophysical colour vision test to use for screening in 3–9 year olds?

Kateri test za oceno barvnega vida je najprimernejši za otroke, stare od 3 do 9 let?

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Izvleček

Izhodišča: Primerjava 4 psihofizičnih testov za oceno barvnega vida in ocena primernosti posameznega testa pri predšolskih otrocih in mlajših šolarjih.

Metode: V raziskavi smo ocenjevali 4 teste. Prvi je bil otrokom prilagojeni test Ishihara (Handaya Co. Ltd., Tokyo), drugi test CVTME (Colour vision testing made easy, T. L. Waggoner, 1994), tretji test Netz (WPS, 2001) in četrti test MRM (Mollon-Reffin Minimalist test, verzija 0.7, 1994). Pri prvih treh je bila otrokova naloga prepoznati simbole na slikah, pri četrtem testu pa je moral poiskati barvni krožec med 5 krožci različnih odtenkov sive. Sodelovalo je 37 otrok z normalnim barvnim vidom (19 deklic in 18 dečkov), starih med 3 in 9 let. Normalni barvni vid smo potrdili, če je otrok vsaj enega izmed 4 testov opravil brez napak. Pri prvih treh testih smo beležili število napak, pri zadnjem pa smo zabeležili najmanj saturirani krožec, ki ga je otrok še prepoznal. Za vsakega od štirih testov smo izračunali specifičnost za posamezno starostno skupino. Vsakega otroka smo tudi vprašali, kateri test mu je najbolj všeč.

Rezultati: 16/37 otrok je naredilo 1 ali več napak pri testu po Ishihari, med njimi vsi mlajši od 5 let. Devet otrok je naredilo 1, trije so naredili 2, dva sta naredila 3 in dva otroka sta naredila 5 napak. 8/37 otrok je naredilo 1–3 napake pri testu CVTME. Štirje otroci so se zmotili enkrat, trije dvakrat in eden trikrat. Vsi otroci so naredili vsaj eno napako pri testu Neitz. Najtežje prepoznaven je bil lik na mestu 6. Dve 3-letni deklici testa Neitz nista bili sposobni z zanesljivostjo izvesti. 10/37 otrok ni opravilo testa MRM brez napake, večina je imela težave v modrem delu barvnega spektra. Najvišjo specifičnost za vse 3 starostne skupine sta imela testa CVTME in MRM. Večini otrok (28/37) je bil najbolj všeč test MRM.

Zaključki: Raziskava je pokazala, da je najpogosteje klinično uporabljan test po Ishihari (analfabetska verzija) za večino mlajših otrok prezahteven in zato nezanesljiv. CVTME se je v raziskavi izkazal za sprejemljivejšega, predvsem za otroke, mlajše od 5 let. Za najmanj zahtevnega se je izkazal test MRM, ki je bil obenem med otroki tudi najbolj priljubljen.

Abstract

Background: To compare 4 psychophysical colour vision tests in children and to decide which test is most suitable for screening in pre-school and early school-age period.

Methods: The first test used was a modified Ishihara plates test (Handaya Co. Ltd., Tokyo). The second test "Colour vision testing made easy" (CVTME) (T. L. Waggoner, 1994) is also based on pseudoisochromatic plates with child-friendly symbols. The third test used was the "Neitz test of colour vision" (WPS, 2001) and the fourth was "Mollon-Reffin Minimalist test" (MRM) (version 0.7, 1994). In the first three tests, the child had to tell what he or she saw in the picture, whereas in the fourth test the child had to pick the coloured button among distractors.

Thirty-seven children (19 girls and 18 boys) from 3–9 years of age with normal colour vision (at least one test should be performed without errors) were tested. The number of errors in each of the first 3 tests was registered, whereas in the MRM test the least saturated button distinguished among distractors was registered. Specificity was calculated for each test. Every child was also asked which was his or her favourite test.

Results: 16/37 children made one or more errors in the modified Ishihara test, among them all children under the age of 5 years. Nine children made 1 error, three made 2, two made 3 and two children made 5 errors. 8/37 children made

1–3 mistakes in the CVTME test. Four children made one mistake, three made two and one child made three mistakes. All tested children made at least one mistake in the Neitz test. All gave a wrong description for the figure in the 6th position of the test. Two 3-year-old girls were not able to perform the test. The MRM test was not performed in full by 10/37 children. Most of these children made errors in the tritan colour vision axis. The highest specificity in all 3 age groups was calculated for CVTME test and MRM test. 28/37 children chose the MRM test as their favourite.

Conclusions: The modified Ishihara colour test has turned out to be too difficult and therefore unreliable in the youngest children. For children under 5 years of age CVTME was more reliable in this study. For all ages the MRM test was the easiest to perform. Most children in this study subjectively preferred the MRM test.

Introduction

Colour vision is an important part of visual perception. Evaluation of colour vision falls within the basic ophthalmologic examination. Colour vision deficiency may be acquired or congenital. Acquired deficiency can result from retinal diseases, or optic nerve and visual pathway pathology. Congenital colour vision deficiency is present in 8–12 % of men and 0.5 % of women and is often inherited recessively linked to chromosome X.[1,2] The most common congenital colour vision deficiency is deuteranomalia, followed by protanomalia, deuteranopia and protanopia. *Deuteranomalia* is present in approximately 5 % of people, all three types of cones are present, with middle-wavelength cones (M) being affected. *Protanomalia* is present in approximately 1 % of people, all three types of cones are present, with long-wavelength cones (L) being affected. *Deuteranopia* is present in approximately 1 % of people, with M cones being absent. *Protanopia* is present in approximatelyt 1 % of people, with L cones being absent.[3]

Colour vision evaluation plays an important role in acquired deficiencies, especially in disease detection and its follow-up. In congenital deficiencies thorough colour vision evaluation is needed for vocational guidance and counselling.

For colour vision evaluation in daily clinical practice different psychophysical tests are used. These tests are based on judging the ability of the patient to compare the same and to differentiate among different colours in a certain colour vision axis. The first group of psychophysical colour vision tests (screening tests) are used to detect colour vision deficiency. Among these tests, Ishihara pseudoisochromatic plates are most widely used. The second group of psychophysical colour vision tests (anomaloscopes, Farnsworth-Munsell hue 100 and D15 tests etc.) are used to grade the deficiency.[1,4] Colour vision evaluation with psychophysical tests is subjective. However, electrophysiological methods can be used to evaluate colour vision objectively. Chromatic visual evoked potentials[5-7] and chromatic electroretinography[8] are still experimental electrophysiological methods which aim to evaluate separate cone function and parvocellular visual pathway integrity.

Most of the psychophysical colour vision tests are designed for testing adults, therefore reliable testing of paediatric population is difficult.[9] Until now, Analphabetic Ishihara plates (Handaya Co. Ltd., Tokyo) were widely used in Slovenia to evaluate colour vision in children. Daily clinical experience has shown that the results obtained using this test are not always reliable, because the test is often too difficult for very young children. One often gets false positive results, which means that a child's colour vision is wrongly estimated as being deficient. There are, however, some psychophysical tests that are designed to test paediatric population, especially preschool children.[10-12]

The purpose of this study was to compare four psychophysical colour vision tests by testing young children and to find out which psychophysical test is most suitable for testing colour vision in this age group.

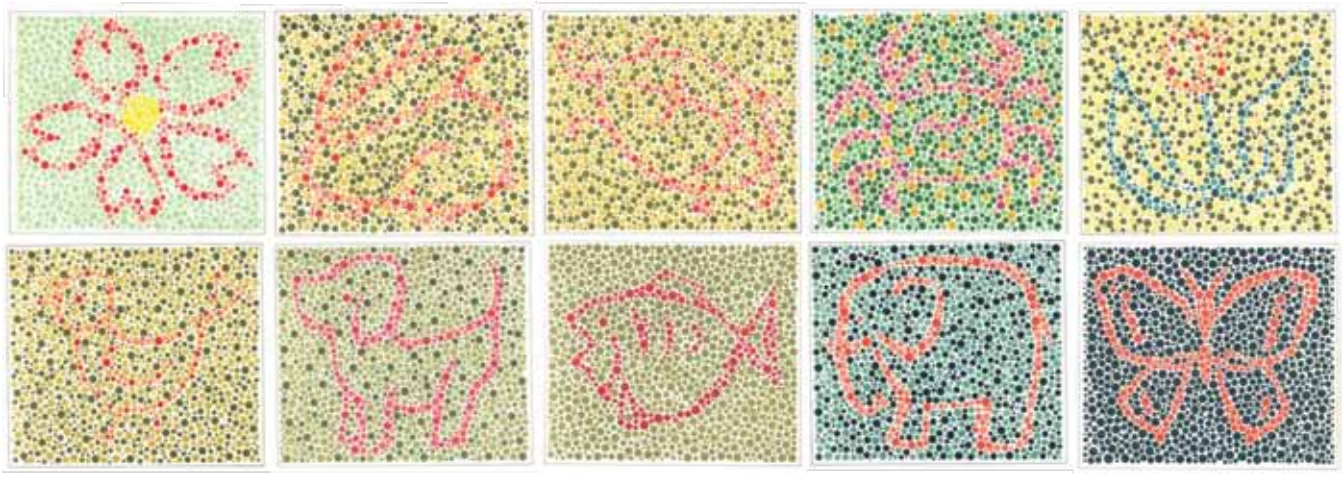


Figure 1: Analphabetic Ishihara test.

Methods

37 children (18 boys and 19 girls) aged 3 to 9 years were included in the study. Children were divided into three age groups. In the first group (3–5 year-olds), 8 children (2 boys and 6 girls) were included. In the second group (5–7 year-olds), 13 children (6 boys and 7 girls) were included. In the third group (7–9 year-olds), 16 children (10 boys and 6 girls) were included. Before testing, informed consent was signed by parents for each child. All children had normal colour vision, which was proven by their ability to perform at least one of the psychophysical tests without a single error. All children who were not able to perform at least one test without error were excluded from the study.

Every child performed the following 4 psychophysical colour vision tests:

1. *Analphabetic Ishihara Test (AI):* is a psychophysical test which is used for screening for colour vision deficiencies in the red-green colour vision spectrum[4]. It consists of 10 pseudoisochromatic plates with animal and flower motifs which have to be recognized by the child. The first plate is the so-called recognition plate, which can also be detected if one has colour vision deficiency. This plate is used to explain the test to the child. Plates that follow have to be recognized in at least 10 seconds, the child has to observe the plates perpendicularly about 75 cm away. Figure 1 shows 10 pseudoisochromatic AI test plates.
2. *Color Vision Testing Made Easy (CVTME)* is a psychophysical colour vision test which was designed by T. L. Waggoner in 1994 and is 100 % Ishihara compatible. The test consists of two parts. The first part consists of a recognition plate and 9 testing plates with simple motifs (star, cir-

Figure 2: Color Vision Testing Made Easy test.

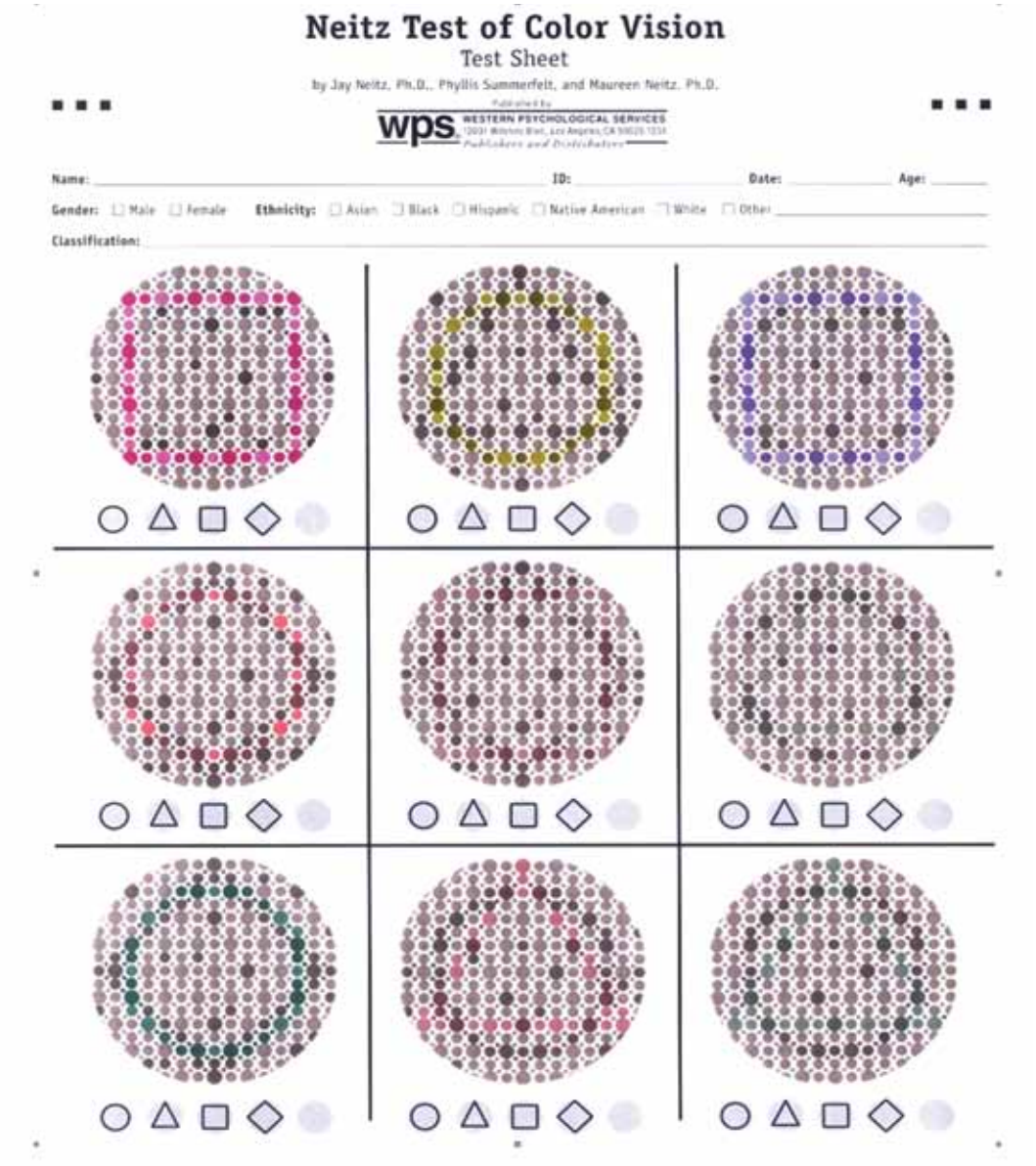


Figure 3: Neitz test of colour vision.

cle, square). There can be several motifs presented on a single plate. The second part comprises a recognition plate and 3 testing plates with slightly more complex motifs (dog, sailing boat, house). The child has to recognize motifs on the plates in no more than 3 seconds, by viewing them perpendicularly from approximately 75 cm distance. With this test, colour vision deficiencies in the red-green spectrum can be detected. The test also allows a certain extent of deficiency grading (by using testing plates with multiple motifs, where one motif is recognized, whereas others are not).[11] Figure 2 shows 10 + 4 pseudoisochromatic CTVME plates.

3. The *Neitz Test of Color Vision (Neitz)* is a psychophysical test which was designed in the Neitz Laboratories (WPS, 2001) and is 100 % Ishihara compatible. The test is a sheet test and is meant to test larger groups of children (school classes, for example). On every sheet of paper there are 9 fields with dot patterns and a child has to identify coloured shapes within grey dot patterns. Below each pattern there are five response options – a circle, a triangle, a square, a diamond and nothing, the correct response has to be marked. With this test, colour vision deficiencies in the red-green and blue-yel-

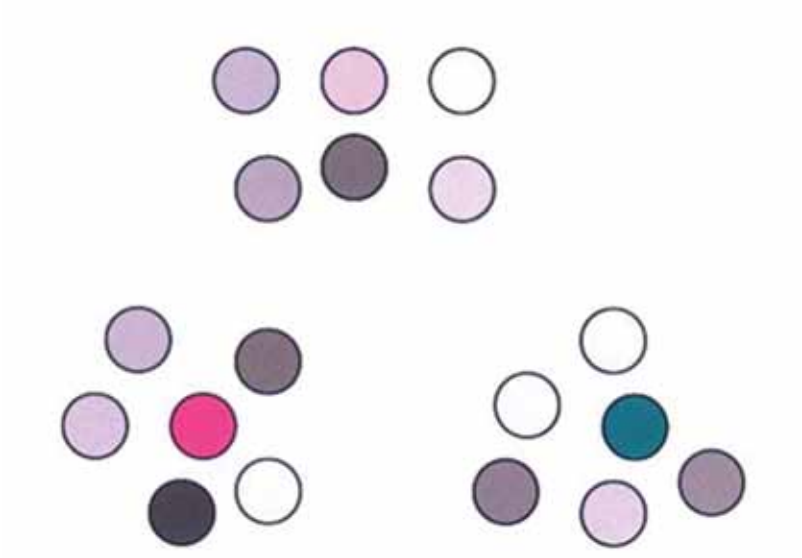


Figure 4: Mollon-Reffin "Minimalist" test.

low spectrums can be detected.[12] Figure 3 shows the Neitz sheet test.

4. The *Mollon-Reffin "Minimalist" test (MRM)* (version 0.7, 1994) is a psychophysical test which was designed by Mollon and Reffin in 1991. The test consists of 5 distractors (grey chips, different greyness) and 1 coloured chip (red, green and blue chips of different saturation). The child has to point the coloured chip among distractors and the examiner replaces the coloured chips with less and less saturated ones. The examiner's task is to establish the least saturated chip that the child can distinguish among distractors. The procedure is repeated for protan, deutan and tritan chips. With this test colour vision deficiencies in the red--green and blue-yellow spectrums can be detected. The grade of colour vision deficiency can also be evaluated.[10] Figure 4 shows a diagram of the MRM test.

For each of the 4 tests the number and type of errors made by an individual child was recorded. The specificity of each test was calculated for each age group. At the end of the testing each child was asked which of the four tests he or she subjectively preferred.

Results

1. Analphabetic Ishihara Test (AI)

21/37 (57 %) children performed the test without a single error, they identified all 10 plates correctly, whereas 16/37 (43 %) children made one or more errors. 9 children made 1 error, 3 children made 2 errors, 2 children made 3 errors and 2 children made 5 errors. The two children with the highest error rate were from the youngest age group (3–5 years). The plates with a rabbit and a tortoise as the motif were found most difficult to identify correctly. Specificity of the AI test for each age group is demonstrated in Figure 5.

2. Color Vision Testing Made Easy (CVTME)

29/37 (78 %) children performed the test without a single error, they identified all 14 plates correctly, whereas 8/37 (22 %) children made one or more errors. 4 children made 1 error, 3 children made 2 errors and 1 child (a four year old girl) made 3 errors. Specificity of the CVTME test for each age group is demonstrated in Figure 5.

3. Neitz Test of Color Vision (Neitz)

None of the children tested were able to perform this test without errors, because of the testing field number 6, which could not be identified by a single child. This test was also too demanding for the two youngest girls (aged 3 years). Among 35 children who were able to perform the test, there were 12 children who made at least one more error besides the one at the field number 6. According to the Neitz scoring system,[12] their colour vision was characterized as deuteranomaly in 9 and protanomaly in 3. Specificity of the Neitz test for each age group is demonstrated in Figure 5.

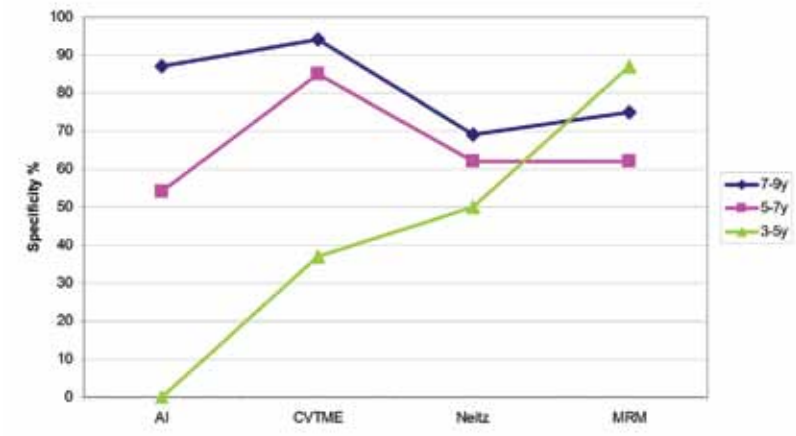


Figure 5: The specificity of each of the four psychophysical tests for each age group.

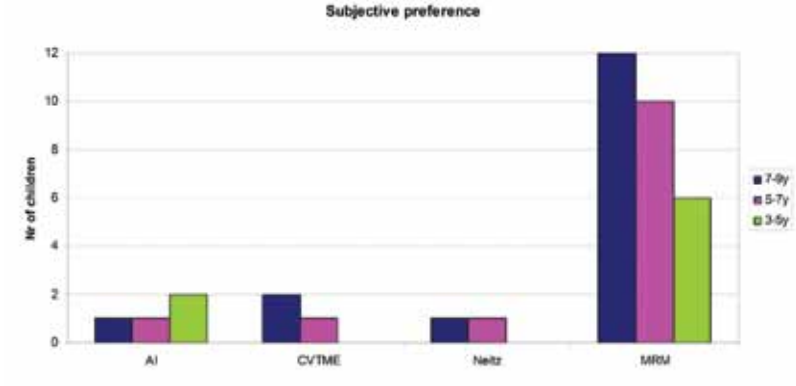
4. Mollon-Reffin "Minimalist" test (MRM)

27/37 (73 %) children performed the test without a single error, whereas 10/37 (27 %) children made one or more errors. Colour vision deficiency was characterized as deuteranomaly in 2, protanomaly in 2, tritananomaly in 4, combined protan- and tritananomaly in 1 and combined deutan- and tritananomaly in 1. Specificity of the MRM test for each age group is demonstrated in Figure 5.

The specificity of each test represents the proportion of children with normal colour vision who were correctly identified as having normal colour vision by a particular test. Figure 5 shows the specificity of each of the four psychophysical tests for each age group.

The results of subjective evaluation in which each child was asked which was his or her favourite test are shown in figure 6. The majority of children from all three age groups preferred the MRM test.

Figure 6: Subjective preference of tests in all age groups.



Discussion

The study has shown that the most frequently used clinical psychophysical colour vision test, the Analphabetic Ishihara test, is not reliable enough and therefore less useful for testing children between ages 3 and 9. It was shown that the "Color vision testing made easy" test is much easier to understand for small children and therefore more reliable. Also, the Mollon-Reffin Minimalist test has shown to be very valuable for testing children, especially because it does not demand any verbal cooperation.

In Slovenia, the most widely used clinical pseudoisochromatic colour vision test is the Ishihara plates test. The same test is often used for testing adults and children. The child has to recognize numbers from the plates, but when he or she does not know the numbers yet, the child is instructed to trace the number with his finger. This kind of colour vision testing is therefore often unreliable especially for preschool children. In a previous study, in which 100 children from 3 to 6 years of age were tested, it was shown that about 4 % of them were unable to perform the test.[13] A better solution is the Analphabetic Ishihara test where numbers are replaced by different motifs (animals, flowers etc.), which should be easier for children to recognize . But the problem is that these motifs are often too complex and therefore the testing score does not always represent the real colour vision status. A study of 1800 children between the ages of 3 and 13 years has shown that about 1–2 % of false positive results can be expected by using this test, in younger children far more than in older.[14] In our study, nearly half of the children tested (43 %) did not identify all of the 10 motifs from the Analphabetic Ishihara test. Most children correctly identified the dog, the fish, the elephant and the butterfly. Most errors were recorded with the rabbit and the tortoise. The results of this study are in favour of simplifying the motifs to be easier for younger children.

The Mollon-Reffin Minimalist (MRM) test has shown the highest specificity among all four tests used in the study. This test is recently widely used for testing young chil-

dren in Great Britain and Canada.[15] The advantage of this test is its short testing time, because the test does not demand high cognitive and motor skills. In this study the specificity of the MRM test was comparable in all three age groups, which has not been shown for any other test. In the 3–5 age group the specificity of the MRM test was the highest (87 %) compared to the other three tests, which also speaks in favour of using this test in youngest children.

The "Color Vision Testing Made Easy" (CVTME) test has shown the highest specificity in both groups of older children. It was 85 % in the 5–7 age group and 94 % in the 7–9 age group. In a previous study, 150 children aged 5–7 years and 40 adults with or without colour vision deficiency were tested with the CTVME test. The study has shown that all children tested were able to perform the test. Test specificity for the adult group was 100 %, whereas test sensitivity was 90 %[11]

The Neitz test has shown to be too demanding for children included in this study. All children made an error at the 6th position, whereas the two youngest girls could not perform the test at all. If the error at the position number 6 is neglected, there were still 40 % of children who made at least one more error. The Neitz test was designed for testing larger groups of children, especially in classes, therefore its sheet design, which was actually very popular with children. The target population for this test are school children[12] and this is also the most probable reason why the results of this test are not that good in the present study.

Subjectively most children preferred the MRM test among all 4 psychophysical tests used in this study. The only task that has to be accomplished in this test is to show the coloured chip among five grey distractors. There is no need for any verbal communication from the child's side and also motor skills needed are very basic, which is probably the reason why this test was the favourite one for all three age groups.

This study has proven our clinical observation that Analphabetic Ishihara test, which was the most widely used clinical test until now, is less reliable for testing colour vision in children under the age of 5. Among all four psychophysical tests used in this study, the authors recommend the "Color Vision Testing Made Easy" test and the Mollon-Reffin Minimalist test. However, there are more potentially useful tests available, such as the Hardy Rand Rittlers – HRR test and the CU Dynamic Colour Vision test, which can be successfully used for testing children. A comparable study would be needed to show which test is most reliable for testing pre-school children.

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