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TIDA: A CHILDREN'S TEST TO ASSESS DYSFUNCTIONS IN THE PERCEPTION OF COLOUR

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After reviewing the controlling factors of alterations in colour perception, their main characteristics and relevance for primary education, we report the results of applying a new test (TIDA) to a population of schoolchildren with ages ranging from 5 to 7 years. Its diagnostic validity and attractiveness to children are compared with two other tests (Ishihara and CUT). TIDA was highly appealing to children and gave a fair estimate of the severity of colour blindness, though its power to discriminate among different types of this problem has still to be improved.

Tras revisar las causas de aparición, características principales, y relevancia escolar de las alteraciones de la percepción del color, se informa de los resultados obtenidos aplicando un nuevo test ("TIDA") a una población escolar formada por 458 niños y 330 niñas, con edades comprendidas entre los 5 y 7 años. Su eficacia diagnóstica y nivel de atractivo se compararon con otros dos test (Ishihara y CUT). El TIDA mostró un alto nivel de atractivo, buenos niveles para diagnosticar la gravedad del daltonismo y niveles mejorables en cuanto al diagnóstico del tipo.

Colour is not a property of objects or surfaces, but an attribute of the perceptual response produced by the brain as a result of the light that hits the retina. More specifically, it is not scientifically correct to state that blood is red or grass is green, though it is correct to say that these are the experiences that tend to occur when the retina receives the light energy reflected by blood or grass.

The chromatic experience of colour-blind people is especially useful for understanding the perceptual nature of colour responses. For example, the same stimulation that normally produces the experience of "orange" would generate in some colour-blind people that of "yellow". Thus, colour cannot be a property of objects, nor of the light reflected by them, since in that case the same stimulus could not give two different chromatic responses.

If colour is a perceptual response and, consequently, belongs to the subjective world of each person's conscious experiences, how is it possible to identify the colours perceived by colour-blind people? Although other procedures can be used (see, e.g., Coren and Hakstian, 1988; Pokorny and Smith, 1979), two types of experiment exist whose results are especially relevant with respect to this question.

The first type requires the collaboration of a "monocular colour-blind" subject. As its name indicates, this condition affects the vision of only one of the eyes. Thus (e.g., Graham & Hsia, 1958; Vriest de Mol & Went, 1971), the experimental subject can be requested to observe, with the colour-blind eye only, a given stimulus, and then to use the non-colour-blind eye ("normal" or "common trichromatic"), to select a stimulus that reproduces in him/her the chromatic experience produced in the observation with the colour-blind eye.

The second type of experiment has been used more frequently (see, e.g., Fletcher and Voke, 1985), as it has been based on the study of the responses of people that are colour-blind in both eyes ("binocular colour-blind" subjects), which is the most common type of colour blindness. In essence, these experiments consist in determining sets of "metameric" stimulations. That is, stimulations that produce the same colour experience despite being physically different. Thus, a colour-blind person may indicate that monochromatic light stimuli that would normally be classified as "greenish" (520 nm), "yellowish" (590 nm) and "reddish" (620 nm) were, for him/her, "the same colour"

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(and therefore metameric). For this subject, all of these stimuli would produce the same kind of sensation.

The data obtained from these two types of experiment concur in indicating that the chromatic world of colour-blind people is a "reduced" and "altered" version of that experienced by humans with normal vision. "Reduced" because it is based on a smaller number of colour categories and/or a more limited capacity for chromatic discrimination (e.g., some colour-blind people lack the categories "green" and "red", and perceive as grey those stimuli that a normal-vision observer would consider as "red" or "green"); "altered" because experiences that are in themselves identical to those occurring in the normal observer may be produced as a response to stimuli that would never provoke such experiences in the normal observer (e.g., colour-blind people would see as "yellow" what would normally be seen as "orange").

What is usually referred to as the "integrated theory of colour perception" (see Lillo, 1993, Chap. 7) provides the most parsimonious conceptual framework for explaining the characteristics of both normal vision and of the "reduced" and "altered" vision found in colour-blind people.

The integrated theory starts out from an initial "trichromatic" phase based on the responses of three types of cone. The first type ("**proto**cones") would be especially sensitive to the longest wavelengths, the second ("**deuto**cones") to medium wavelengths, and the third ("**trita**cones") to short wavelengths. This functional differentiation would allow us to explain why some stimuli give rise to the perception of different colours (those that activate in different ways the three types of cone), while others, in spite of being physically different, produce the same colour (those that produce an identical pattern of activity in the cones would be **metameric**). Importantly, this trichromatic phase would also explain why colour-blind people perceive a large number of metamers, and why there are different types of colour blindness.

Let us begin by looking at the different types of colour blindness, pointing out that we can make a distinction between the more severe cases ("dichromatic") and those that are less serious ("anomalous trichromatic"). Among the former, the most common cause would be the absence in the retina of one of the three types of cone, the suffix "anopia" being used to indicate this condition in technical denominations. Thus, if we consider as the "first" type of cone that which is especially sensitive to long wavelengths, and as the "second" type that which is sensitive to medium wavelengths, it would seem appropriate to call the types of colour blindness derived from the absence of the first and second cone type "**prot**anopia" and "**deu**teranopia", respectively, since, in Greek, "**proto**" and "**deutera**" mean "first" and "second". Obviously, the lack of one of these types of cone would lead to the person experiencing a considerably larger number of metamers than normal, since it is easier for two stimuli to affect in a different way two types of cone (which is what happens in dichromatics) than it is for them to affect three (which is what happens in trichromatics). This is why a colour-blind child would perceive as similar, or metameric, stimulations that in a common trichromatic child would give rise to clearly distinct colour experiences.

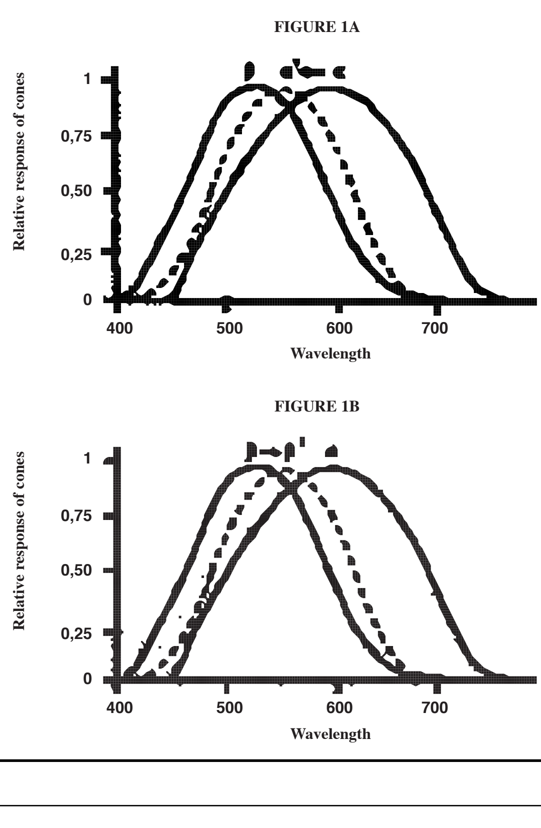
The terms most commonly used to refer to mild colour blindness are "**prot**anomaly" and "**deut**eranomaly", the causes of these alterations obviously being the existence of some problem or "anomaly" related to the first ("prota") or second ("deutera") type of cone. Although for a long time different possibilities were considered for ascertaining in what this anomaly actually consisted (see, e.g., Wasserman, 1978), microspectrophotometric measurements made in the last two decades (Pokorny & Smith, 1982) have shown that the cause of these types of alteration is related to the increment in the degree of overlap between the spectral response curves of protocones and deutocones.

In more specific terms, and as Figure 1 shows, a protanomaly would occur when the maximum response of the protocones takes place in the presence of a shorter-than-normal wavelength (displacement of the spectral curve to the left), while in the case of deutanomalies the problem would be that the maximum response in the deutocones occurs in the presence of a longer-than-normal wavelength (displacement of the spectral curve to the right). In any case, the smaller the separation between curves –or the greater their overlap–, the lower the probability of obtaining different responses in proto- and deutocones, and, therefore, the higher the probability of the appearance of metameric colours.

As we have just seen, the peculiarities of the trichromatic coding phase allows us to understand the reason for the clinical terms corresponding to the different types of colour blindness, and why, in people suffering from this type of disorder, the phenomenon of metameric colours occurs with excessive frequency. However, in order to understand the nature of the chromatic experiences of colour-blind people, we must proceed a step further in the integrated theory, to the level of opponent "processes" or "mechanisms" (Abranov & Gordon, 1994; Hurvich, 1981).

The activity generated in the cones is used by the visual system as an input for three different types of perceptual mechanism. The activity of these mechanisms is related to the detection of three different types of imbalance in the light energy that reaches the observer and produces the experience of different attributes in colours ("light-dark", "red-green", "blue-yellow"). The first of them, which can be termed "achromatic", "light-dark" or "black-white", bases its functioning on the comparison of the quantities of light coming from neighbouring areas. The other two, which are called "chromatic", are essential with regard to the hue, and are based on the search for relative accumulations of energy in different parts of the spectrum. Thus, the red-green mechanism would respond to the presence of a predominance of medium wavelengths (green) or of any of those at the extremities (red), while the activation of the "blue-yellow" mechanism would indicate a predominance of wavelengths in the short (blue) or long (yellow) portion of the spectrum.

FIGURE 1



It is easy to predict the existence in colour-blind people of functional problems in the opponent mechanisms, since these mechanisms use the responses of the cones, and these responses are altered in colour blind people. Specifically, the greatest alteration would consist in a reduction in the functional capacity of the "red-green" mechanism, which would be maximal for dichromatics ("protanopes" and "deutanopes" would not have the experiences of green and red), and less marked for anomalous trichromatics (the experiences of "red" and "green" would have a relatively low intensity, and would only occur in the presence of stimuli that a normal person would consider as having "very bright colours"). Finally, we should make reference to the existence of people with a functional alteration in the "red-green" mechanism in the absence of perturbations at the level of photoreceptors. Such people would be those traditionally referred to as "non-specific colour-blind", and whom Hurvich (1981) calls "neuteranomalous" or "neuteranopes", depending on the degree of seriousness of their problem.

Although they do not produce effects as severe as in the "red-green" mechanism, the alterations of the receptors characteristic of most types of colour blindness also affect the functioning of the "blue-yellow" and "achromatic" mechanisms. Concerning the former, it should be pointed out that colour blind people differ, both among themselves and with respect to those with normal vision, in terms of the degree to which they experience "yellowish" or "bluish" components in chromatic stimulations. Much more importantly, and situating ourselves now in the ambit of the achromatic mechanism, in "**protans**" (**prota**nopes and **prota**nomalous subjects), there is a significant reduction in the capacity for responding to long-wavelength energy. Thus, a colour-blind child may think a low-intensity reddish light is switched off, or confuse a "red" drawing with a "black" or "dark grey" one. These types of effect are so well known that, during the early decades of this century, it was common to refer to protan anomalies as "red blindness".

The important limitations of the chromatic world of colour-blind people were soon taken into account in the world of work, with the realisation of the dangerous implications for certain professions. For example, it is not difficult to imagine the consequences of a protanope signal-box attendant failing to see a red alarm light; or a security guard confusing a green "security" light with a "warning" or "danger" red light. Thus, norms were soon established with the aim of restricting the access of colour-blind people to certain professions (see, e.g., Voke, 1980).

In clear contrast to what has happened in the labour world, little attention has been paid, until recently, to the study of chromatic capacities in schoolchildren. Bearing in mind that colour blindness affects 4 to 8% of the male population (Pokorny & Smith, 1986; Fletcher & Voke, 1985; Birch, 1993), that colours are frequently used in the school context as a means of facilitating the acquisition of certain knowledge and, finally, that the learning of the colours themselves is one of the objectives of early education, how can we explain the scant regard for the measurement of this aspect of perception? Among other reasons, we might mention the following:

1. Certain studies made in the late 1960s and early 1970s (e.g., Mandola, 1969; Lampe et al., 1973; see also Perales and cols., 1986) failed to detect important effects of anomalies in the perception of colour on levels of educational achievement.
2. Most of the tests capable of rapid testing of chromatic capacities and, therefore, those used for assessing relatively large populations, are not designed for application to young children. To give an especially notorious example, while the first adult version of Ishihara's classic test dates from 1917 (Birch, 1993), and has been widely used throughout the world since that time, the version specifically designed for children was not introduced in England until 1990 (op. cit.), and is still not applicable in Spain.
3. Given their price and their scarce utility in follow-up programs, tests for detecting chromatic alterations have had a quite limited distribution.

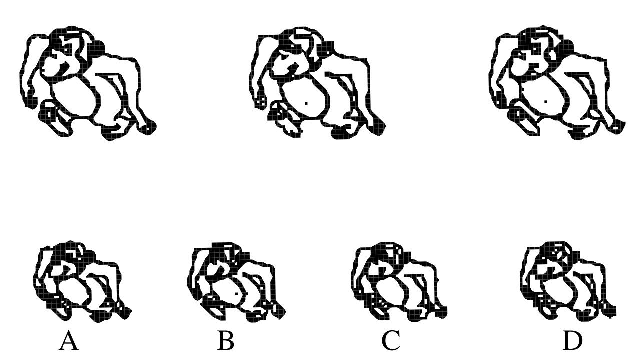
None of the reasons listed above need present a problem today. To begin with, although it may be true that colour blindness does not always impair academic performance (Mandola, 1969; Lampe et al., 1973), it is also true that it acts as an obstacle to the carrying out of certain academic tasks (Knowlton & Woo, 1989), that ignorance of it tends to result in emotional responses from children affected (Voke, 1984), and that these children, compared to common trichromatics, are more likely to change their vocational preferences, since they initially choose professions incompatible with their limitations (Taylor, 1971, 1977). Taking all of this into account, it would seem recommendable to assess chromatic capacities from an early age.

The test that constitutes the central concern of this paper, the TIDA (***T****est de* ***I****dentificación de* ***Da****ltonismos*, or Test for the Detection of Colour Blindness), seeks to contribute to reducing some of the obstacles that have hindered the assessment of chromatic capacities in children in this country –namely: (1) the absence of attractive and easily-understood tests for small children; (2) the high cost of the existing ones; and (3) the fact that those available are of little use in helping children to understand the nature of their limitation and, therefore, to reduce the possibilities of it becoming a problem.

What characteristics does the TIDA have that might enable it to overcome these obstacles? Figure 2 gives us some idea, showing as it does the general model from which the illustrations used in the test are derived. As it can be seen, there are two sets of monkeys, which can be coloured in using different colours. The type of drawing used is similar to those commonly found in schoolchildren's books and stories, allowing the test to be presented as though it were part of a game, with the perceptual task used for making the diagnosis being integrated into this "game". The procedure is quite simple, since it merely consists in the subject indicating which of the monkeys from the bottom row "look like", "are similar to" or "are brothers of" those of the top row. More precisely, as the upper monkeys are always grey, the task involves indicating which of the lower ones are also grey, the existence of colour blindness being detected when the child selects, along with those that are genuinely grey, one of the monkeys a child with normal vision would describe as "coloured".

Being based on the use of pseudoachromatic stimuli

Figure 2



("grey" only for colour-blind people), the test allows the identification of the group of colours that presents most difficulties for each child and, therefore, provides valuable information for subsequent compensatory programmes. Moreover, with a minimum of complementary explanation, the nature of the problem can be made understandable to parents and teachers.

With the aim of assessing whether the characteristics of the TIDA indeed helped to produce the desired results, the test was used with a sample of schoolchildren at the lower age limit for the applicability of two tests, Ishihara and CUT (City University Test), both of which are widely used and well regarded within the field of colour blindness detection (Birch, 1993; Fletcher & Voke, 1985). The combined use of these three tests (TIDA, CUT and Ishihara) allowed us to evaluate both the diagnostic capacity of the TIDA and its appeal to children.

METHOD

Subjects

The research was carried out in 10 schools in Madrid and one of its suburbs, Majadahonda, with children whose ages ranged from 5 to 7 years at the beginning of the 1994-95 school year. The sample was made up of a total of 788 children (330 girls and 458 boys).

Materials

We used a battery composed of the tests Ishihara, CUT and TIDA.

As is well known, Ishihara's classic test uses a series of sheets on which certain numbers can be identified (e.g., "seven" or "forty-two"), provided the figures and the background on which they are presented are perceived as being of different colours.

The Ishihara test was applied in two different ways. In the first application, the "simplified version", a limited group of sheets was used in order to make the task easier for the children. Specifically, we used those with the following identification numbers: 1, 2, 3, 6, 8, 10, 13, 14, 15, 18, 19, 22 and 23. In the second application, the "complete version", all of the sheets (1 to 25) from the 1988 version were used.

Given that many children had difficulties in identifying verbally the two-figure numbers, they were allowed to emit their "number-response" figure by figure ("one and four", instead of fourteen). In some cases, moreover, children were permitted to trace with the finger the form of the number they said they recognised (if they were unable to identify it verbally).

The second of the tests used, the CUT (City University Test) consists of 11 sheets (1 training + 10 diagnostic), on which is presented a central reference pattern and around it four alternatives from among which the subject must indicate which is most similar to the central pattern. In all of the diagnostic sheets one of the alternatives corresponds to that which a person with normal chromatic vision would select, while the three remaining figures correspond to the three classic types of alteration ("protan", "deutan" and "tritan").

The TIDA is a test using pseudoisochromatic illustrations especially designed for child subjects. There are 8 sheets (2 training + 6 diagnostic), whose general structure is shown in Figure II. As already indicated, all the sheets show two groups of monkeys (3 larger ones on the top row and 4 smaller ones on the bottom row) with different functions. The function of those on the top row is to act as reference elements for the type of stimuli the child must look for in those on the bottom row ("grey" or "colourless"); the function of the illustrations on the bottom row is to present the alternatives from which the child must select those he/she perceives as achromatic.

In order to obtain a wide range of greys, we used in the upper line of monkeys a range of reflectancies that went from 15% to 70%. These values correspond, in subjective terms, to "very dark grey" and "very light grey", respectively, being very close to the colours of reference S 2500-N and S 8500-N in the Spanish colour norms (AENOR, 1994).

The lower portion of the two training sheets (1 E and 2 E) permitted the colour-blind and normal-vision children to respond in the same way, by using chromatic stimuli with similar effects in the two types of subject. Specifically, Sheet 1 E presented two achromatic stimuli and two chromatic, while Sheet 2 E showed three achromatic stimuli and one chromatic stimulus.

The 6 diagnosis sheets presented among the lower monkeys two stimuli that were perceived in the same way by all types of observer (one achromatic and another chromatic). The two remaining monkeys belonged to the "pseudoachromatic" category, i.e., clearly coloured for normal-vision subjects, but possibly achromatic for colour-blind people. One of these stimuli was located in the chromatic area of the "greens", while the other was situated in that of the "reds". The position occupied by each one of the 4 types of monkey described varied from sheet to sheet.

Three of the six diagnosis sheets used stimuli aimed at being pseudoachromatic for protan-type alterations; the rest did the same for deutan-type alterations. Within each one of these groups of three, three different levels of saturation were used (one per sheet), in order to be able to differentiate between more and less severe colour blindness.

The measurement of the chromatic co-ordinates corresponding to the different sheets of the TIDA test was carried out by means of a photocolourmeter Minolta CS-100.

In order to control the light conditions in which the tests were applied, we used a Luxo-Photometer Gossen-Mastersix. The use of the appropriate apparatus allowed us to confirm whether the level of illumination (between 60 and 200 lx) and the colour temperature (between 4000 and 6000 K) were suitable for the tests. Whenever possible we used sunlight only. When this was not the case, the sunlight was complemented by light generated with incandescent bulbs of tungsten filament filtered so as to reach a colour temperature of 4000 K.

PROCEDURE

The test battery was applied during school hours in the months of March, April and May 1995. All of the schools had some room with conditions of light and space that were suitable for the simultaneous assessment of children in small groups (3-4).

After informing the children that they would be using three different "colour games", they were presented sequentially with the three tests. The order of presentation was varied using a fully randomised procedure (Pereda, 1987). After the application of the test battery, the child was presented with a sheet from each one of the tests, and asked to say which of them "he/she liked the most", insisting that he/she must choose only one of the three.

Any test which had produced a response different from that which would be expected in a child with normal vision was immediately repeated. In those cases where the response corresponded to a pathological model, the diagnosis was confirmed through a further application of the test battery 3-4 weeks after the original session.

RESULTS

In this section two types of results are analysed. The first type (see Figure 3) relates to preferences among the tests; the second (see Table III) concerns their diagnostic capacity.

Figure 3 shows the percentages of selections for each test on considering "globally" the entire population assessed, and when taking each of the three educational levels ("pre-school", "first grade" and "second grade") separately. Height of the bars corresponds to the percentages. The sum of the three frequencies corresponding to the global population is only 537 (294+132+111=537), since this was the number of children providing responses that were clear and under suitable conditions in the test selection task. Of the rest of the 788 to whom the

Figure 3

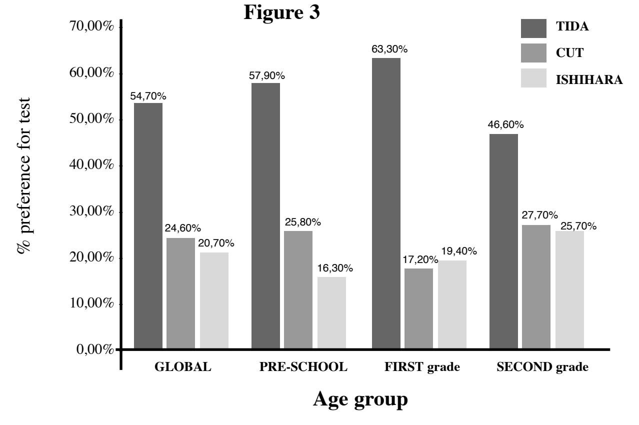


Table 1
Comparison among the preference levels corresponding to each test

PRE-SCHOOL		
TYPE OF COMPARISON	χ^2	PROBABILITY
AMONG THE THREE	66,6	0,000**
TIDA Vs ISHIHARA	54,39	0,000**
TIDA Vs CUT	28,84	0,000**
CUT Vs ISHIHARA	4,97	0,026*
FIRST		
TYPE OF COMPARISON	χ^2	PROBABILITY
AMONG THE THREE	73,03	0,000**
TIDA Vs ISHIHARA	41,89	0,000**
TIDA Vs CUT	47,51	0,000**
CUT Vs ISHIHARA	0,24	0,622
SECOND		
TYPE OF COMPARISON	χ^2	PROBABILITY
AMONG THE THREE	11,85	0,003**
TIDA Vs ISHIHARA	8,98	0,003**
TIDA Vs CUT	7,13	0,003**
CUT Vs ISHIHARA	0,11	0,73
GLOBAL		
TYPE OF COMPARISON	χ^2	PROBABILITY
AMONG THE THREE	112	0,000**
TIDA Vs ISHIHARA	82,69	0,000**
TIDA Vs CUT	61,61	0,000**
CUT Vs ISHIHARA	1,81	0,18

tests were applied, some said they were very tired after carrying out the tasks, others did not wait to have all three tests in front of them before making a choice, while others could not decide which they preferred.

The first impression one has on looking at Figure 3 is that children preferring the TIDA were in a majority, both in global terms and by educational levels. This situation, as indicated by the analyses of χ^2 (chi-square) shown in Table I, was confirmed with very high levels of significance.

The second noteworthy aspect of Figure 3 concerns the differences between the percentages corresponding to the tests CUT and Ishihara, with a tendency for the former to be preferred. The application of the corresponding analyses of χ^2 (Table I) indicated that this difference was only significant in the case of the "pre-school" group.

The third aspect of interest with regard to the data in Figure 3 is not so marked as the previous two, and concerns the change in the magnitude of preference for the TIDA. Specifically, if we compare **the difference** in height between the bars corresponding to percentages for TIDA and the other tests (CUT and Ishihara) in the "second grade" group, we see that this difference is smaller than that found for the "pre-school" and "first grade" groups. This would indicate that for older children the preference for TIDA was not so strong. The results of a series of χ^2 indicated that, indeed, the pattern of preferences among the tests was different in the "second grade" children with respect to any of the other two groups (second vs pre-school: χ^2=6.28; p=0.043; second vs first: χ^2=9.54; p=0.008). The two younger groups, on the other hand, did not differ from one another (pre-school vs first: χ^2=4.4; p=0.11).

In contrast to the case of age group, sex of the children did not influence the pattern of preferences, neither for the population overall (χ^2=1.19; p=0.55), nor by school level ("pre-school": χ^2=2.68; p=0.26; "first": χ^2=0.59; p=0.74; "second": χ^2=0.16; p=0.92).

Let us move on to a comparison of the diagnostic capacity of the three tests. To begin with, it should be pointed out that the "final diagnosis" for each child was made, as Fletcher and Voke (1985) recommend in this type of study, by combining the diagnoses provided by the tests Ishihara and CUT, both with regard to type of pathology ("protan", "deutan", "non-specific"), and seriousness of the problem ("severe problem=dichromatism or severe anomalous trichromatism"; moderate problem=moderate and mild anomalous trichromatisms"). Table II shows a breakdown of the 24 cases detected in the diagnostic categories used. All alterations detected were in male children.

The "final diagnosis" was compared with those we shall refer to as "possible diagnoses", this latter group being made up of diagnoses that would have been made from the application of each one of the three tests alone, or the combination of TIDA with any of the other two (TIDA + ISHIHARA = Comb. 1); (TIDA + CUT = Comb. 2). When, for a given subject, the "final diagnosis" and one of the "possible diagnoses" coincided, there was "agreement"; in the opposite case, there was "disagreement".

Table III shows the frequencies of "agreements" and "disagreements" between each of the 5 "possible diagnoses" and the "final diagnosis". In IIIA the comparison concerns only the diagnosis of "type" of problem; in

Table 2
Detected cases of alterations in the perception of colour, specifying type and severity

LEVEL		PROTAN	DEUTAN	NON-SPECIFIC	TOTAL
	SEVERE	7	9	1	17
	MODERATE	1	2	4	7
	TOTAL	8	11	5	24

Table 3
Agreements and disagreements between "possible diagnoses" and "final diagnosis"

III "A"
Possible diagnosis with respect to TYPE OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
AGREEMENT	18	14	14	21	17
DISAGREEMENT	6	10	10	3	7

III "B"
Possible diagnosis with respect to TYPE OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
AGREEMENT	20	17	20	22	22
DISAGREEMENT	4	7	4	2	2

III "C"
Possible diagnosis with respect to TYPE OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
AGREEMENT	14	13	13	20	17
DISAGREEMENT	10	11	11	4	7

IIIB the comparison refers to the diagnosis of its "severity". In IIIC, "agreement" required the coincidence in the diagnoses of both "type" and "severity" of the problem.

With the aim of comparing among one another the 5 "possible diagnoses", a series of analyses of χ^2 was applied (substituted where necessary by Fisher tests) to the frequencies shown in each of the three parts of Table III, obtaining the results that appear in Table IV. As it can be observed, it was statistically significant that the diagnosis of "type" based on the exclusive use of the tests "CUT" and "TIDA" gave rise to a lower frequency of agreements than that obtained from a combination of TIDA with Ishihara (Comb. 1).

As far as the diagnosis of the level of "severity" is concerned, the CUT test showed a tendency to be inferior to the rest of the partial diagnoses that neared statistical significance when it was compared with Combinations 1 and 2.

The analyses shown in Table IV refer to diagnostic capacity when both "type" and "severity" of the problem are considered. In this case it was observed that any of the tests alone tended to be less effective than the combination of TIDA and Ishihara (Comb. 1). This tendency reached levels of statistical significance in the cases of CUT and TIDA, and neared it in the case of Ishihara.

The second type of analysis applied to the frequencies in Table III consisted in a series of binomial tests to determine the degree of probability with which we could expect to obtain the frequencies of "agreements" and "disagreements" corresponding to each of the "possible diagnoses" in each type of diagnosis ("type", "severity", "type and severity"). The data shown in Table V indicates that any of the "possible diagnoses" offered a percentage of agreements significantly higher than what would have been expected by choosing each of the diagnostic categories at random. The percentages to be expected in that case were: 33% (expected frequency 7.92) for severity (categories: "severe", "moderate", "no problem"); 25% (expected frequency 6) for type (categories: "protan", "deutan", "non-specific", "no problem"); and 14% (expected frequency 3.43) for the combination of "type" and "severity" ("severe protan", "moderate protan", "severe deutan", "moderate deutan", "severe non-specific", "moderate non-specific", "no problem").

Table 4
Results of the analyses of χ^2 applied for comparing the 5 possible diagnoses shown in Table 3

	TYPE		SEVERITY		TYPE AND SEVERITY	
	χ^2	p	χ^2	p	χ^2	p
ISIHA-CUT	1,5	.22	1,06	.30	0,08	.77
ISIHA-TIDA	1,5	.22	0,0	1.0	0.08	.77
ISIHA-COMP1	1,23	.26	0,76	.38	3,63	.56-
ISIHA-COMP2	0,11	.75	0,76	.38	,81	.36
CUT-TIDA	0,0	1.0	1,06	.30	0,0	1.0
CUT-COMP1	5,17	.022*	3,41	.06-	1,42	.23
CUT-COMP2	0,82	.37	3,41	.06-	1,42	.23
TIDA-COMP1	5,17	.022*	0,76	.38	4,75	.03*
TIDA-COMP2	0,82	.37	0,76	.38	1,42	.23
COMP1-COMP2	2,02	.16	0,0	1,0	1,06	.30

DISCUSSION

The results obtained by the TIDA test can be described as "very encouraging", with respect to both its attractiveness (it was the test that received most preferences) and its diagnostic capacity. In more specific terms, the TIDA has the advantages of: (1) consisting of a small number of sheets or illustrations, allowing its rapid application; (2) being based on a task that is easy for children. It was probably because of this, and given its graphic characteristics, that this test was found to have the most appeal, especially among the youngest children. Moreover, these advantages were accompanied by the fact that levels of diagnostic capacity very similar to those of the other two tests were found.

Table 5
Results of the binomial analyses applied to the data in Table 3

"A"
Possible diagnosis with respect to TYPE OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
Prop. Observed	0,75	0,583	0,583	0,875	0,708
Test prop.	0,25	0,25	0,25	0,25	0,25
Binomial	p=0,0000	p=0,0005	p=0,0005	p=0,0005	p=0,0000

"B"
Possible diagnosis with respect to SEVERITY OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
Prop. Observed	0,833	0,708	0,833	0,916	0,916
Test prop.	0,33	0,33	0,33	0,33	0,33
Binomial	p=0,0000	p=0,0005	p=0,0005	p=0,0005	p=0,0000

"C"
Possible diagnosis with respect to TYPE AND SEVERITY OF ALTERATION

	Ishihara	CUT	TIDA	Comb. 1	Comb. 2
Prop. Observed	0,583	0,541	0,541	0,833	0,708
Test prop.	0,142	0,142	0,142	0,142	0,142
Binomial	p=0,0000	p=0,0000	p=0,0000	p=0,0000	p=0,0000

It is well accepted in the literature (see, e.g., Birch, 1993; Fletcher and Voke, 1985) that the combination of different tests always provides better results than the application of any one of them alone. Thus, the fact that such a result was also obtained in our research is not surprising. However, comparison between the "possible diagnoses" from the exclusive use of TIDA and those derived from its use combined with any of the other two seems to indicate that the greatest weakness of TIDA concerns its capacity for diagnosing the "type" of problem.

How can we improve this aspect of the TIDA, at the same time maintaining the advantages we have already mentioned? In our view, the best solution would be to include in it a "second part" specifically designed to differentiate between the different types of colour blindness. Such a "second part" is already being designed, and would be applied only to children for whom the "first part" (the only one used in this study) had detected the presence of problems in the perception of colour.

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