Data from the
NATIONAL HEALTH SURVEY

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Number 118

Color Vision Deficiencies in Children

United States

Prevalence of color vision deficiencies, as identified on examination with plates from the Ishihara Test and typed with the Hardy-Rand-Rittler Test, among children of 6-11 years by age, sex, race, family income, and area of residence.

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Series 11 reports present findings from the National Health Examination Survey, which obtains data through direct examination, tests, and measurements of samples of the U.S. population. Reports 1 through 38 relate to the adult program; additional reports concerning this program will be forthcoming and will be numbered consecutively. The present report is one of a number of reports of findings from the children and youth programs, Cycles II and III of the Health Examination Survey. These reports, emanating from the same survey mechanism, are being published in Series 11 but are numbered consecutively beginning with 101. It is hoped this will guide users to the data in which they are interested.

Vital and Health Statistics - Series 11-No. 118

NATIONAL CENTER FOR HEALTH STATISTICS

DIVISION OF HEALTH EXAMINATION STATISTICS

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In accordance with specifications established by the National Health Survey, the Bureau of the Census, under a contractual agreement, participated in the design and selection of the sample, and carried out the first stage of the field interviewing and certain parts of the statistical processing.

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CONTENTS

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COLOR VISION DEFICIENCIES IN CHILDREN

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INTRODUCTION

This report presents prevalence data on color vision deficiencies in children 6-11 years of age in the noninstitutional population of the United States as estimated from the Health Examination Survey (HES) findings. While these data were collected in the period 1963-65, the prevalence of this primarily inherited condition can be expected to remain fairly constant in the population since that time.

Color vision deficiency, commonly called color blindness, manifests itself in everyday life in the confusion of, or blindness to, one or more primary colors, and its origins may be congenital or acquired.[1,2] Congenital defects occur in two chief forms, total and partial. The former is very rare and is generally associated with nystagmus and a central scotoma. All colors appear as grays of differing brightness. The partial form is the most common type of color vision defect and is primarily an inherited condition transmitted through the mother, who is usually unaffected. It is probably due to the absence of one of the photopigments normally found in the foveal cones.[2] In most cases reds and greens are confused.

Acquired defects of color vision may often develop in the course of ocular, mainly retinal, disease.[1] Red-green defects are frequently characteristic of lesions of the optic nerve and optic pathways, while blue-yellow defects are more likely to result from lesions of the outer layers of the retina.[2]

Source of the Data

The Health Examination Survey, on which this report is based, is one of the major programs of the National Center for Health Statistics, authorized under the National Health Survey Act of 1956, by the 84th Congress, as a continuing Public Health Service activity to determine the health status of the population.

The National Health Survey is carried out through three distinct programs.[3] One of these, the Health Interview Survey, is concerned primarily with the impact of illness and disability upon the lives and actions of people. It collects information from samples of people through household interviews. A second program, Health Resources, obtains health data as well as health resource and utilization information through surveys of hospitals, nursing homes, other resident institutions, and the entire range of personnel in the health occupations. The Health Examination Survey is the third major program.

The Health Examination Survey collects data by direct physical examinations, tests, and measurements performed on the sample population under study. This approach provides the best method of obtaining actual diagnostic data on the prevalence of certain medically defined illnesses. It is the only way to secure information on unrecognized and undiagnosed conditions and on a variety of physical, physiological, and psychological measures within the population. The survey also collects demographic and socioeconomic data on the sample population under study to which the examination findings may be related.

The Health Examination Survey is conducted as a series of separate programs referred to as "cycles." Each cycle is limited to some specific segment of the U.S. population and to certain specific aspects of the health of that population. In the first cycle, data were obtained on the prevalence of certain chronic diseases and on the distribution of various physical and physiological measurements and other characteristics in a defined health population.[4,5]

For the second cycle, on which this report is based, a probability sample of the Nation's noninstitutionalized children 6-11 years of age was selected and examined. The 3-hour examination focused primarily on health factors related to growth and development. It included examinations conducted by a pediatrician and a dentist, tests administered by a psychologist, and a variety of additional tests and measurements performed by a technician. The survey plan, sample design, examination content, and operation have been described previously.[6]

Field collection operations for the cycle were begun in July 1963 and completed in December 1965. Of the 7,417 children selected in the sample, 7,119, or 96 percent, were examined. This national sample is representative of the approximately 24 million noninstitutionalized children 6-11 years of age in the United States. During a single visit to the mobile units specially designed for use in the survey, each child was given a standarized examination by the examining team. Prior to the examination, information relating to demographic and socioeconomic characteristics of household members as well as medical history, behavioral, and related data on the child to be examined were obtained from the parent. Information on the child's grade placement, teachers' ratings of behavior and adjustment, and details of any health problems known to the teachers were requested from the school each child attended. Birth certificates were obtained for verification of the child's age and for facts relating to the child at birth.

Statistical notes on the survey design, reliability of data, and sampling and measurement error are shown in appendix I. Definitions of demographic terms used in this report are given in appendix II.

COLOR VISION EXAMINATION

The vision examination consisted of tests to detect and classify color vision deficiencies, both monocular and binocular tests to measure the level of central visual acuity at distance and near, tests for lateral phoria at distance and near and of vertical phoria at distance, a test for bilateral accommodation at distance, and distance and near tests for binocularity. Except for color vision, tests were performed without glasses or other refractive lenses for those who normally wore them.

In addition, each child was given an eye examination by the survey staff pediatrician. The examination included a careful inspection of the eyes for evidence of styes, conjunctivitis, blepharitis, nystagmus, and ptosis as well as tests to detect the presence and type of strabismus. This report is limited to findings on the color vision tests. An earlier report describes results of the visual acuity tests.[7]

The Color Vision Tests

Two of the most reliable and widely used color vision tests commercially available were selected for the survey—The Ishihara Test for Colour-Blindness (1960 edition, 24 plates, seven of which were used) and the American Optical Company's Hardy-Rand-Rittler Pseudoisochromatic Plates (1957 edition, 24 plates). These permitted uniform testing in the time limit available and were suitable for large-scale administration to children 6 through 11 years of age. Both tests consist of pseudoisochromatic plates, which are based on the fact that the color defective individual sees no difference between two or more color samples which appear different to persons with normal color vision.[1,2] These plates contain numerals or other figures represented in dots of various tints set on a neutral background amid dots of the same size but of tints which are most readily confused with those of the figures by persons with the principal types of color vision deficiencies. Individuals with color vision deficiencies are unable to see any numbers or patterns on some of the plates; on others they may see a different number or pattern than that seen by persons with normal color vision.

The Ishihara Test

The Ishihara Test for Colour-Blindness was first published in Japan in 1917 and in its various editions has been used extensively in color vision testing. This test has been found to be very effective in differentiating between persons with normal and deficient color vision.[9-14] The 1960 edition, part of which was employed in the Health Examination Survey, consists of 24 plates designed to detect the existence of a color vision deficiency.[8] Seven of the plates found most reliable were used for screening in this survey.[10] These require the ability to identify correctly one or two colored numerals or their absence.

The Hardy-Rand-Rittler Pseudoisochromatic Plates

The commerical version of the Hardy-Rand-Rittler test (H-R-R) was first produced by the American Optical Company in 1955 and was based on the H-R-R Polychromatic Plates developed earlier.[15] In 1957 a second commerical edition of the H-R-R, which was used in this study, was published. It consisted of four demonstration plates, six screening plates, and 14 diagnostic plates of the pseudoisochromatic type.[16] This H-R-R test is designed to serve three purposes:

1. A screening test to separate persons with defective color vision from those with normal color vision.
2. A qualitative diagnostic test to classify type of color defect (whether protan, deutan, tritan, and tetartan).
3. A quantitative diagnostic test to indicate degree or severity of the defect.

The H-R-R requires only the ability to identify and indicate the position of the colored circles, triangles, and crosses. The neutral background pattern of the plates is composed of small, gray circular dots of varying sizes and shades. Set amid the gray dots are dots of similar sizes but of colors which are confused with gray by persons who have any of the principal types of defective color vision. These colored dots are arranged in any quadrant of the plate. A single test plate carries one or two of these symbols. The colored dots, like the background dots, vary in size and shades. In successive plates these symbols are presented in graded steps of chroma.

Two general types of color vision deficiencies are classified by the H-R-R—red-green deficiencies, which comprise most congenital color vision deficiencies, and the much rarer blue-yellow deficiencies. The H-R-R further distinguishes three subtypes of red-green deficiencies, protan, deutan, and "red-green undetermined." The particular errors made on the plates determine the classification.[1,8,13,16] Protan deficiencies are characterized by decreased sensitivity for red and its complementary hue, blue-green. These colors appear as gray or as an indistinct grayish color to the individual with a protan type deficiency.

Deutan is the term given to the decrease in sensitivity for pure green and its complementary hue, red-purple. These colors are seen as gray or as an indistinct color close to gray by persons with deutan type deficiencies. Persons whose red-green deficiency could not be classified as protan or deutan are assigned the diagnosis "red-green deficiency undetermined as to type." Blue-yellow deficiencies are classified by the H-R-R as tritan or tetartan or as "blue-yellow deficiency undetermined as to type." Tritan and tetartan deficiencies indicate loss of sensitivity in the blue-yellow perceptual area. To the tritan there is confusion of yellow-green with gray, and for the tetartan blue or yellow is confused with gray.

The H-R-R test is also designed to provide a measure of the degree of deficiency through its graded series of plates in which there is an increasing saturation of the critical hues. Three degrees of severity of defect are recognized in the H-R-R—mild, medium, and str ng. The classification is based on the last group of plates in which errors occur. Only a rough quantification of the degree of defect can be made in this manner, and it is recognized that pseudoisochromatic plates do not reliably distinguish among other classifications of color vision deficiency such as "anomalous trichromates" or "dichromats."[13,17]

Evaluations of the Hardy-Rand-Rittler test indicate that it is a reliable technique for screening normals and abnormals, and for providing qualitative diagnoses of red-green color vision deficiencies.[9,11,15] The test has also been favorably evaluated as a technique for quantitative diagnoses of red-green defects.[12,15] The paucity of individuals with blue-yellow defects has prevented validation of the plates designed to detect the rare tritan and the controversial tetartan form of defective blue-yellow vision.[16]

The first four plates in the H-R-R test are demonstration plates. The next six plates make up the screening series, followed by 14 plates in the diagnostic series. Fourteen of the test plates are concerned with red-green deficiencies, and six are devoted to the detection and the qualitative and quantitative diagnosis of blue-yellow defectives.

Testing Methods

In the survey of children, color vision testing preceded the other vision tests. The tests were performed binocularly with glasses or other corrective lenses on if the child normally wore them. Test books were placed on a table under a Macbeth Easel Lamp having an intensity of from 20-28 foot candles, as measured weekly by light meter at the table level. This is the type of illumination and within the intensity range recommended by the authors of the H-R-R test for valid testing.[16] The Easel Lamp provides sufficient intensity of the desired quality so that a small amount of extraneous light in the room will not appreciably affect the results of the tests. The child was seated at the testing table so that his eyes were kept about 30 inches from the test book. Each child was first administered seven plates of the Ishihara test (plates 1, 2, 5, 8, 11, 14, and 16) as a screen to separate children with normal color vision from those with color vision deficiencies. If the child had difficulty identifying the numbers on the plates he was asked to trace the figure he saw with a small paint brush. Responses to each plate were entered on a special recording form (appendix III).

Children who correctly read the Ishihara plates were classified as having normal color vision and testing was terminated. Failure to correctly read any one of the screening plates except plate 1, which was used as a demonstration plate, indicated the possibility of a color vision deficiency, and the child was then administered the Hardy-Rand-Rittler Test to verify his deficiency.

The first four plates of the H-R-R were administered first. These plates are used for demonstration purposes to acquaint the child with the symbols he will see in the subsequent plates.

Plates 1-6, the screening plates, were then administered. The child was asked the number of colored symbols he saw, their shape, and their location on the plates. A correct answer to all three parts was required to receive credit toward a rating of normal color vision. Answers were entered on the special recording sheets (appendix III).

If the child gave the correct response for all six screening plates, he was considered to have normal color vision and no further testing was done. This occasionally occurred after one or more incorrect responses on the Ishihara plates. In a few instances, the examiners continued H-R-R testing for children when it seemed warranted despite the fact that the H-R-R screening plates were read correctly. Children making one or more errors on the H-R-R screening plates were then given the diagnostic series to determine the specific type of deficiency, i.e., protan, deutan, etc., and severity of the defect, i.e., mild, medium, or strong. All qualitative and quantitative diagnoses in this report are based on H-R-R protocol.

FIELD ADMINISTRATION AND QUALITY CONTROL

Vision tests were administered by the survey staff examining dentist because that member of the survey team had the time available for them. The effect of this was to have these tests conducted by a professional person who, once the necessary special training had been given, was highly adept at administering the tests. Each of the five dentists employed during the cycle was given training and practice in vision testing techniques to insure consistency of test results. Further practice was obtained during the "dry runs" preceding the start of the regular examinations at each of the 40 areas in which the mobile Health Examination Centers were located. Replicate examinations, given 136 children at three of the examination locations during the cycle, showed identical results on test and retest in the detection of those with defective color vision.

Testing equipment and illumination were checked weekly throughout the cycle to insure that recommended standards were met.

FINDINGS

General Screening Results

Screening results from the shortened form of the Ishihara test indicated that an estimated 95 percent of the children 6-11 years of age in the United States probably had normal color vision, based on finding from the Health Examination Survey during 1963-65. These children achieved perfect, or normal, scores on the six Ishihara screening plates used (table 1). About 4.6 percent of the children misread at least one of the Ishihara screening plates. For a very small number of children (0.2 percent), neither the Ishihara test nor the H-R-R was given. About 3.7 percent of the children tested failed both the Ishihara and H-R-R screening plates, while 0.2 percent failed the Ishihara plates but passed the H-R-R screening plates. Approximately 0.7 percent of the children failed the Ishihara screening plates but were not tested further on the H-R-R plates. These test omissions were due primarily to fatigue or illness on the part of the child, or to lack of time to complete the vision examination, and occurred mostly among the youngest children (table 1).

Mean Ishihara screening scores and percent distributions of children by scores on the Ishihara screening plates are shown according to sex and age in table 2. No clear relationship between age and performance on the Ishihara was evident, though 6-year-olds were slightly more likely than older children to make at least one error on the screening plates. At all ages, boys were much more likely to misread at least one plate than were girls.

Table 3 presents the distribution of H-R-R screening scores of those 3.9 percent of the children who were administered this test. The relatively small number of girls who were given the H-R-R precludes the presentation of any reliable distribution of scores according to age.

All further prevalence findings in this report are based on H-R-R test protocol. Children for whom complete test results on the H-R-R were not available were excluded from the prevalence findings reported below. It was in effect assumed that the proportion with defective color vision among that small group would be essentially the same as among those for whom test results were available.

Prevalence Rates

About 3.80 percent, or approximately 900,000 children, 6-11 years of age in the noninstitutional population of the United States had color vision deficiencies as estimated from Health Examination Survey findings in 1963-65 using the Hardy-Rand-Rittler test (tables 4 and A). Sex differences in prevalence were apparent, with boys about 13 times as likely to have color vision deficiencies as girls. About 6.95 percent of the boys had deficiencies, while only 0.53 percent of the girls were affected.

Among boys race appeared to be significantly related to the presence of color vision deficiency. About 7.44 percent of white boys exhibited a deficiency, while the comparable figure for Negro boys was 4.04 percent. Negro girls showed a slightly higher prevalence rate than did white girls, but the difference was not statistically significant. No cases of color vision deficiency were detected among children of "other races," who comprised about 0.5 percent of the sample and included American Indians, Chinese, Japanese, and people of any race other than white or Negro.

Table A. Prevalence rates for color vision deficiencies among children 6-11 years of age by race and sex: United States, 1963-65

Race and sex	Estimated number of children affected	Rate per 100 children
Both sexes		
Total	902,000	3.80
Boys		
Total	839,000	6.95
White	773,000	7.44
Negro	66,000	4.04
Girls		
Total	63,000	0.53
White	50,000	0.50
Negro	13,000	0.76

Type of Deficiency

Among both boys and girls red-green types of deficiencies occurred much more often than blue-yellow defects (table 4). Of the approximately 6.95 percent of the boys showing evidence of some color vision deficiency, 92 percent, or 6.41 percent of all boys tested, exhibited difficulties only in the red-green perceptual area. About 0.46 percent showed decreased sensitivity in both the red-green and blue-yellow perceptual areas. A very small number, 0.07 percent, showed evidence of blue-yellow deficiencies only. The preponderance of red-green deficiencies over other types was true for both white and Negro boys. Of the approximately 0.53 percent of the girls diagnosed as color vision defective, 66 percent, or 0.35 percent of all girls tested, were found to have deficiencies involving only the red-green perceptual area, while the rest showed evidence of both red-green and blue-yellow deficiencies. No deficiencies in blue-yellow color vision only were detected among girls in the survey.

Red-Green Deficiencies

About 6.88 percent of the boys and 0.53 percent of the girls 6-11 years of age in the United States were found to exhibit decreased sensitivity in the red-green perceptual area, the most common form of color vision deficiency (table 5). These figures include a small percentage of individuals who also showed evidence of blue-yellow deficiencies (table B). White boys exhibited a significantly higher red-green prevalence rate (7.36 percent) than did Negro boys (4.04 percent). Negro girls had a slightly higher rate than white girls, but the difference was not statistically significant. Statistically significant sex differences in prevalence were apparent for both races, but the differences were most marked among white children (figure 1). The prevalence of red-green

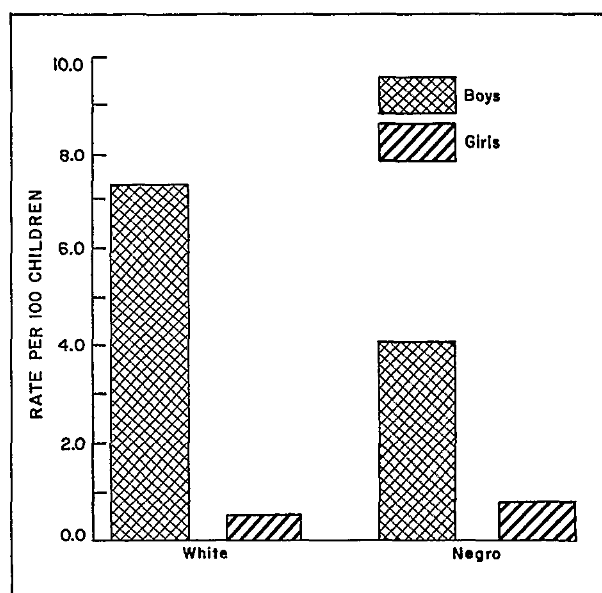

Figure 1. Prevalence rates for red-green color vision deficiencies among children 6-11 years of age, by race and sex: United States, 1963-65.

Table B. Prevalence rates for color vision deficiencies among children 6-11 years of age, by type of defect, race and sex: United States, 1963-65

Race and sex	All red-green deficiencies	All blue-yellow deficiencies	Red-green and blue-yellow deficiencies
Both sexes	*Rate per 100 children*		
Total	3.76	0.36	0.32
Boys			
Total	6.88	0.53	0.46
White	7.36	0.57	0.49
Negro	4.04	0.30	0.30
Girls			
Total	0.53	0.18	0.18
White	0.50	0.16	0.16
Negro	0.77	0.34	0.34

defects for white boys was almost 15 times as great as the prevalence for white girls (0.50 percent), while Negro boys were about 5 times as likely to be affected as were Negro girls. Age did not appear to be significantly related to the prevalence of red-green type deficiencies.

Severity—Prevalence rates for each of the three degrees of red-green deficiency obtained from Hardy-Rand-Rittler test protocol are shown by sex and race in table 6. Among white boys, the cases of color vision deficiency were distributed fairly evenly by severity. Among Negro boys red-green defects of the strong type were found more often than were those of lesser degrees, but none of the differences in prevalence among the three categories of severity were statistically significant. Among the relatively few girls who showed evidence of a red-green deficiency, almost all deficiences were of the mild type.

Subtype—Among boys the predominant subtype of red-green deficiency observed was the deutan type, affecting about 3.85 percent of the male population (table 7). Among boys with red-green deficiencies, deutan type defects accounted for about 56 percent of the diagnoses.

Protan type defects were observed in about 2.15 percent of the boys, a deutan to protan ratio of 1.78 to 1.00. White boys exhibited a significantly higher prevalence of protan deficiencies than did Negro boys, while Negro boys showed a slightly higher prevalence of deficiencies of the undetermined type than did white boys.

Among girls the most frequently observed red-green diagnostic category was the undetermined type; however, the prevalence was very small (0.35 percent). The small number of Negro girls detected in the survey as having red-green deficiencies were all classified in the red-green undetermined category.

Prevalence rates for the three subtypes of red-green deficiencies according to severity are shown by sex and race in table 8. The estimated rates for Negro boys and for girls of both races are based on a small number of cases and hence subject to high sampling variability but are included along with their standard errors of estimate to convey the overall findings from the nationwide survey.

Red-green prevalence rates for boys exceeded those for girls in almost every diagnostic category. In seven of the nine diagnostic categories by type and degree, rates for white boys exceeded those for Negro boys.

Among boys, protan type deficiencies tended to be of strong degree, while among boys with red-green deficiencies of undetermined type, mild defects predominated.

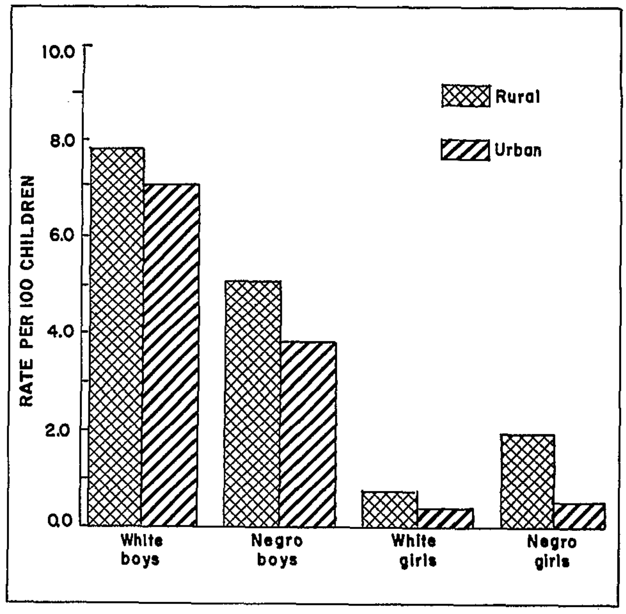

Figure 2. Prevalence rates for red-green color vision deficiencies among children 6-11 years of age, by race, place of residence, and sex: United States, 1963-65.

Red-Green Deficiencies by Selected Demographic Variables

Region—Because of the small number of girls affected, analysis of regional variations in the prevalence of red-green color vision deficiencies was limited to boys. Among white boys, prevalence rates for red-green deficiencies ranged from 6.25 percent in the Midwest to 8.98 percent in the Northeast (table 9). None of the differences, however, were statistically significant. Similarly, no statistically significant differences were observed in regional prevalence rates among Negro boys.

Place of residence—Children living in places designated as rural according to 1960 census definitions tended to have slightly higher prevalence rates of red-green deficiencies than those living in urban areas (table 10 and figure 2). This finding was true for boys and girls of both races, although differences between individual sex-race groups were not statistically significant. The finding may be a reflection of sampling variability, and without additional data no explanation can be offered.

Family Income—Analysis of variations in the prevalence of red-green deficiencies among different income groups was limited to data for white boys, the only group for which a sufficient number of cases was available to provide reliable data. Among white boys, the prevalence of red-green color vision deficiencies tended generally to increase slightly as family income increased (table 11 and figure 3). However, none of the differences in prevalence between income groups were statistically significant. As was true of the analysis by place of residence, the findings may reflect sampling variability.

Blue-Yellow Deficiencies

Blue-yellow deficiencies as diagnosed by the Hardy-Rand-Rittler test were discovered in

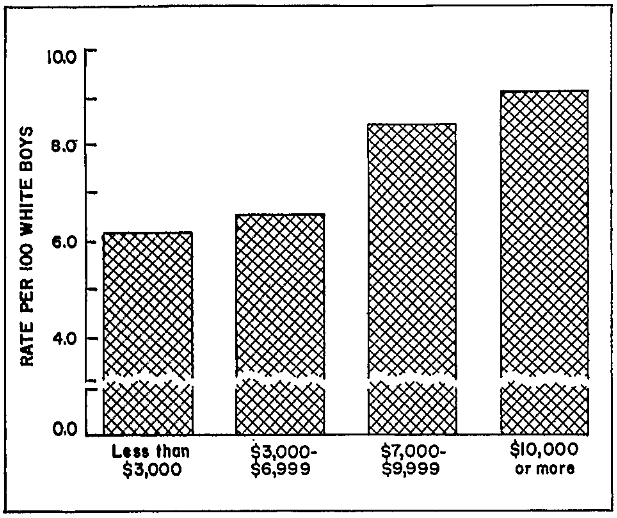

Figure 3. Prevalence rates for red-green color vision deficiencies among white boys 6-11 years of age, by annual family income: United States, 1963-65.

an estimated 0.36 percent of the U.S. population aged 6-11 years, or about 87,000 children (table 12). Most of the boys and all the girls with blue-yellow deficiencies also had accompanying red-green deficiences (table B).

Sex differences in prevalence were apparent for white children but not for Negroes.

The blue-yellow prevalence for white boys, 0.57 percent, was significantly higher than the comparable figure for white girls, 0.16 percent. Among Negro children, the prevalence rates for boys and girls were similar. White boys had a slightly higher prevalence (0.57 percent) than Negro boys (0.30 percent), but the difference was not statistically significant, nor was the difference in prevalence between white and Negro girls.

Severity and Subtype—Among the small number of boys and girls with blue-yellow deficiencies, defects of the mild type predominated (table 12). Almost all of the blue-yellow deficiencies identified by the Hardy-Rand-Rittler test were of the tritan type (table 13). Tritan type deficiencies occurred in about 0.46 percent of the boys and 0.13 percent of the girls, a statistically significant difference. All tritan deficiencies observed in the survey were of the mild type. A very small number of children (about 0.03 percent) were diagnosed as having tetartan type deficiencies as a result of their errors on the color vision tests.

Both Red-Green and Blue-Yellow Deficiencies

An estimated 0.32 percent of the children 6-11 years of age in the United States had color vision deficiencies involving both the red-green and blue-yellow perceptual areas based on findings from the Health Examination Survey (table 14). Among white children, the prevalence rate for boys (0.49 percent) exceeded that for girls (0.16 percent), but the difference was not statistically significant. Among Negro children, the rates for boys and girls were similar. No statistically significant differences were found by race.

Further information on the specific combinations of red-green and blue-yellow deficiencies found among the children examined in the survey is presented in appendix IV.

COMPARISON WITH OTHER STUDIES

Defective color vision, or color blindness as it is commonly known, has attracted the attention of scientists since its discovery in the late 18th century.[18] Many surveys of color vision have been conducted, most performed outside the United States and most utilizing testing instruments and procedures somewhat different from those of the Health Examination Survey. Reviews of these studies appear in articles by Post, Kherumian and Pickford, and Kalmus.[18-20] General findings from some of these studies are presented in table C for comparison with national estimates for American children from the present study. The list of earlier studies in table C is not exhaustive. The studies selected for comparison were primarily based on large-scale testing performed on subgroups of white European or American populations or American Negro populations. Most utilized the Ishihara Test or the H-R-R. A few also employed the anomaloscope, a precise instrument for determining defective color vision. In most cases findings are presented only for red-green color vision deficiencies.

Findings from the present study appear to agree generally with those of other major studies. Among 33 samples of white males from

Table C. Selected studies reporting prevalence of red-green color vision deficiencies

Author and year	Reference No.	Population	Male		Female		Test used
			Number	Rate per 100	Number	Rate per 100	
European studies							
Waaler, 1927	21	Norwegian students	9,094	8.01	9,072	0.44	Ishihara and anomaloscope
Von Planta, 1928	22	Swiss students	2,000	7.95	3,000	0.43	Ishihara and anomaloscope
Wieland, 1933	23	Swiss students	1,036	8.2	—	—	Ishihara and anomaloscope
Schmidt, 1936	24	Germany	6,863	7.75	5,604	0.36	One setting of anomaloscope
Vernon and Straker, 1943	25	British males	12,344	7.25	—	—	A-O Pseudoisochromatic Plates
Grieve, 1946	26	British Air Force aircrew candidates	16,180	6.63	—	—	Ishihara
Francois and others, 1957	27	Belgian schoolboys	1,243	[1]8.61	—	—	Ishihara, anomaloscope and Farnsworth Tritan Plate
Mann, 1956	28	Australia	558	7.3	327	0.6	Ishihara
Kherumian and Pickford, 1959	20	France	6,635	8.95	6,990	0.50	Ishihara
Brown, 1951	29	Scottish students	525	7.43	252	0.46	Ishihara
Crone, 1968	30	Netherlands	3,167	7.95	3,359	0.45	Ishihara, H-R-R, and others
U. S. studies							
Haupt, 1922	31	Baltimore, Maryland school children	448	7.8	487	1.6	Nela Test (colored wool skeins)
Miles, 1929	32	College students	1,286	8.2	436	0.9	Ishihara
Garth, 1933	34	Colorado Whites	795	8.4	232	1.3	Ishihara
		Negroes in Southern U. S.	538	3.9	496	0.8	
Clements, 1930	33	American Negroes					Ishihara
		Fullblood	205	3.4	—	—	
		Mixed blood	118	4.2	—	—	
Crooks, 1936	35	Negroes, Virginia	2,019	3.9	722	0.1	Ishihara
Sweeney and others, 1964	36	Negro boys in New York City	1,137	6.77	—	—	Screened by H-R-R
				2.99	—	—	Screened by anomaloscope
Thuline, 1964	13	Students in Takoma, Washington	5,263	6.14	5,078	0.45	Ishihara and H-R-R
Shearron, 1965	37	Students in Tennessee	676	5.67	619	0.32	H-R-R
		White	548	6.83	—	—	
		Negro	128	3.12	—	—	
U. S. Health Examination Survey, 1963-65		Representative nationwide sample of children 6-11 years of age in the noninstitutional population of the U.S.					Ishihara and H-R-R
		White	3,153	7.36	2,947	0.50	
		Negro	464	4.04	523	0.77	

[1] Includes red-green and other defects.

Europe and the United States reviewed by Post, most of the rates for red-green deficiency lie fairly close to 8 percent.[19] The present finding of 7.36 percent prevalence for red-green deficiencies among white males in this country approximates this figure. It is, however, slightly larger than Thuline's study of Takoma, Washington, school children, in which a red-green prevalence rate of 6.14 percent was found for white males.[13] The rate for white girls in the United States from the present study, 0.50 percent, is similar to the findings of Thuline, who using the Ishihara and H-R-R found a red-green prevalence rate of 0.45 percent among 5,078 Takoma, Washington, schoolgirls.

For Negro males, the national rate for red-green deficiencies of 4.04 percent based on H-R-R testing is lower than Sweeney's study of New York City Negro boys (6.77 percent screened as red-green color defective using the H-R-R). Anomaloscope testing in Sweeney's study reduced the rate to 2.99 percent.[36] The national rate in the present study is in agreement with the range of 3 to 4 percent reported by Clements, Garth, and Crooks.[33-35] The prevalence rate for American Negro girls in the present study, 0.77 percent, coincides with Garth's figure of 0.8 percent.[34]

The finding that an estimated 0.37 percent of white children in the United States showed evidence of blue-yellow deficiencies, though a very small prevalence, is much larger than previous estimates of 0.002 percent (Wright)[41] and 0.08 percent (Thuline).[13] Almost all the cases detected through the Health Examination Survey in the present study were of the mild tritan type, and most had accompanying red-green color deficiencies. The rate for blue-yellow defects found among Negro males in the present study, 0.30 percent, is also slightly higher than the findings of Sweeney and others (0.2 percent).[36] This unexpected frequency of tritan type defects has been noted in the literature, and hence it is possible that mild blue-yellow deficiencies are not as rare as previously thought.[30, 39] The preponderence of males over females with red-green deficiencies has been observed in most studies of white populations. The higher prevalence of red-green defects among white males over that for Negro males has also been reported in other studies. The finding from this study of no statistically significant relationship of color vision defects with age among American children within the age range of the population studied is in accord with earlier studies by Chapanis and Thuline.[13,40]

SUMMARY

National estimates based on Health Examination Survey findings from a probability sample representative of children 6-11 years of age in the noninstitutional population of the United States show:

1. About 3.80 percent or 900,000 of these children were affected by color vision deficiencies. Boys were affected much more often than were girls. About 6.95 percent of boys showed evidence of color vision deficiences, while only 0.53 percent of the girls were affected. White boys were affected significantly more often than were Negro boys.
2. Red-green types of defects far outnumbered blue-yellow deficiencies, affecting 6.88 percent of the boys and 0.53 percent of the girls.
3. White boys had a significantly higher prevalence of red-green deficiencies (7.36 percent) than did Negro boys (4.04 percent).
4. Age did not appear significantly related to the prevalence of red-green deficiencies.
5. Red-green deficiencies in girls tended to be of the mild type, while among boys cases were distributed fairly evenly by severity.
6. Among boys, deutan type defects were found more often than any other (3.85 percent of all boys tested).
7. No statistically significant regional differences in the prevalence of red-green deficiencies were observed among boys, though some variation did occur. Children from rural areas tended to have slightly higher prevalence rates than those living in urban areas. Among white boys, the prevalence of red-green deficiency tended to increase slightly as family income increased.

8. Blue-yellow deficiencies were found in an estimated 0.36 percent of the population, affecting about 0.53 percent of the boys and 0.18 percent of the girls. Most children with blue-yellow deficiencies also had accompanying deficiencies in the red-green perceptual area. Most blue-yellow deficiencies were of the mild type, and almost all (in 0.30 percent of the population) were tritan type defects.
9. About 0.32 percent of the children had color vision deficiencies involving both red-green and blue-yellow perception.

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LIST OF DETAILED TABLES

Table 1. Percent distribution of children by general screening results of color vision testing, according to age and sex: United States, 1963-65

Age and sex	All children	Passed Ishihara	Failed Ishihara				Neither test given
			Total	Failed H-R-R	Passed H-R-R	Not tested on H-R-R	
	Percent distribution						
Both sexes							
6-11 years	100.00	95.15	4.59	3.73	[1]0.17	0.69	0.22
Boys							
6-11 years	100.00	91.85	7.96	6.83	0.23	0.90	0.16
6 years	100.00	90.07	9.37	6.62	0.32	2.43	0.53
7 years	100.00	93.37	6.19	4.89	0.11	1.19	0.41
8 years	100.00	92.23	7.75	7.50	0.13	0.12	-
9 years	100.00	92.32	7.66	6.84	0.44	0.38	-
10 years	100.00	91.68	8.30	6.98	0.40	0.92	-
11 years	100.00	91.43	8.55	8.26	-	0.29	-
Girls							
6-11 years	100.00	98.56	1.12	0.53	0.11	0.48	0.29
6 years	100.00	97.40	1.69	0.54	0.33	0.82	0.89
7 years	100.00	98.24	1.53	0.76	-	0.77	0.22
8 years	100.00	99.05	0.82	0.31	0.22	0.29	0.11
9 years	100.00	98.78	0.85	0.69	-	0.16	0.34
10 years	100.00	98.65	1.16	0.41	0.12	0.63	0.17
11 years	100.00	99.33	0.66	0.48	-	0.18	-

[1]Includes a very small number of children (0.05 percent) who were tested further on the H-R-R diagnostic plates though they passed the H-R-R screening plates.

Table 2. Mean Ishihara screening scores and percent distribution of children by Ishihara screening scores, according to age and sex: United States, 1963-65

Age and sex	Mean score	Total	Number of screening plates read correctly						
			6	5	4	3	2	1	0
Both sexes		Percent distribution							
6-11 years----------	4.5	100.00	95.37	0.53	0.25	0.46	0.60	1.43	1.32
Boys									
6-11 years----	4.5	100.00	92.00	0.75	0.37	0.64	1.16	2.50	2.54
6 years-------------	4.6	100.00	90.55	1.72	0.39	0.78	1.33	3.67	1.53
7 years-------------	4.5	100.00	93.76	1.30	0.28	0.69	0.52	1.37	2.03
8 years-------------	4.4	100.00	92.23	0.13	0.27	0.44	1.04	2.76	3.10
9 years-------------	4.6	100.00	92.32	0.50	0.27	0.98	1.46	2.34	2.09
10 years------------	4.5	100.00	91.68	0.79	0.54	0.47	0.97	2.53	2.99
11 years------------	4.4	100.00	91.43	-	0.50	0.47	1.65	2.30	3.61
Girls									
6-11 years----	4.5	100.00	98.85	0.31	0.12	0.27	0.03	0.32	0.06
6 years-------------	4.3	100.00	98.27	0.49	0.14	0.57	-	0.50	-
7 years-------------	4.7	100.00	98.46	0.79	0.13	-	0.10	0.50	-
8 years-------------	4.6	100.00	99.16	0.24	0.24	0.18	-	0.16	-
9 years-------------	4.5	100.00	99.13	-	0.13	0.32	0.12	0.13	0.13
10 years------------	4.2	100.00	98.82	0.12	0.11	0.33	-	0.60	-
11 years------------	4.7	100.00	99.33	0.18	-	0.24	-	-	0.24

Table 3. Percent administered H-R-R and percent distribution of children by H-R-R screening score, according to age and sex: United States, 1963-65

Age and sex	Percent administered H-R-R	Total	Number of screening plates read correctly						
			6	5	4	3	2	1	0
Both sexes		Percent distribution							
6-11 years	3.90	100.00	4.59	6.61	7.40	20.14	55.01	3.94	2.28
Boys									
6-11 years	7.06	100.00	3.40	5.52	6.32	19.88	58.84	3.87	2.12
6 years	6.94	100.00	4.67	4.85	2.19	17.01	58.61	4.18	8.45
7 years	5.00	100.00	2.30	12.12	12.68	27.26	39.54	2.91	3.16
8 years	7.63	100.00	1.78	3.67	9.77	8.73	69.59	4.72	1.71
9 years	7.28	100.00	6.20	7.97	-	15.19	64.26	6.37	-
10 years	7.38	100.00	5.55	3.65	7.33	28.72	54.73	-	-
11 years	8.26	100.00	-	3.08	7.50	24.76	59.98	4.65	-
Girls									
6-11 years	0.64	100.00	17.88	18.71	19.42	23.09	12.12	4.70	4.05
6 years	0.87	100.00	*	*	*	*	*	*	*
7 years	0.76	100.00	*	*	*	*	*	*	*
8 years	0.53	100.00	*	*	*	*	*	*	*
9 years	0.69	100.00	*	*	*	*	*	*	*
10 years	0.53	100.00	*	*	*	*	*	*	*
11 years	0.48	100.00	*	*	*	*	*	*	*

Table 4. Percent distribution of children 6-11 years of age by color vision status, according to race and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All children	Normal color vision	Defective color vision			
			Total	Red-green only	Blue-yellow only	Red-green and blue-yellow
	Percent distribution					
Both sexes						
Total	100.00	96.20	3.80	3.43	0.03	0.32
Boys						
Total	100.00	93.05	6.95	6.41	0.07	0.46
White	100.00	92.56	7.44	6.87	0.08	0.49
Negro	100.00	95.96	4.04	3.73	-	0.30
Girls						
Total	100.00	99.47	0.53	0.35	-	0.18
White	100.00	99.50	0.50	0.34	-	0.16
Negro	100.00	99.23	0.77	0.42	-	0.34
	Standard error					
Both sexes						
Total	-	-	0.26	0.27	0.02	0.08
Boys						
Total	-	-	0.46	0.52	0.04	0.14
White	-	-	0.47	0.54	0.04	0.16
Negro	-	-	1.24	1.13	-	0.28
Girls						
Total	-	-	0.13	0.10	-	0.04
White	-	-	0.13	0.11	-	0.05
Negro	-	-	0.52	0.31	-	0.28

Table 5. Prevalence of red-green color vision deficiencies among children, by race, age, and sex, with corresponding standard errors: United States, 1963-65

Age and sex	Total	White	Negro	Total	White	Negro
Both sexes	Rate per 100 children			Standard error		
6-11 years	3.76	3.99	2.41	0.26	0.27	0.75
Boys						
6-11 years	6.88	7.36	4.04	0.48	0.49	1.24
6 years	6.82	7.35	3.65	1.14	1.24	2.21
7 years	4.75	4.90	3.90	0.70	0.72	1.49
8 years	7.53	7.74	6.43	1.06	1.23	3.72
9 years	6.83	7.66	1.87	0.95	1.06	1.37
10 years	7.22	8.03	2.16	1.41	1.50	2.12
11 years	8.26	8.61	6.24	1.56	1.83	2.94
Girls						
6-11 years	0.53	0.50	0.77	0.13	0.13	0.52
6 years	0.54	0.41	*	0.32	0.30	*
7 years	0.76	0.71	*	0.35	0.38	*
8 years	0.31	0.21	*	0.23	0.22	*
9 years	0.70	0.81	*	0.28	0.32	*
10 years	0.41	0.29	*	0.26	0.22	*
11 years	0.48	0.55	*	0.48	0.56	*

Table 6. Prevalence of red-green color vision deficiencies among children 6-11 years of age, by severity of defect, race, and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All red-green defects	Severity			All red-green defects	Severity		
		Mild	Medium	Strong		Mild	Medium	Strong
Both sexes	Rate per 100 children				Standard error			
Total------------	3.76	1.35	1.05	1.36	0.26	0.16	0.12	0.16
Boys								
Total------	6.88	2.20	2.05	2.62	0.48	0.27	0.24	0.32
White------------	7.36	2.32	2.32	2.72	0.49	0.28	0.27	0.30
Negro------------	4.04	1.53	0.38	2.11	1.24	0.73	0.29	1.18
Girls								
Total------	0.53	0.46	0.02	0.04	0.13	0.12	0.02	0.03
White------------	0.50	0.45	0.02	0.02	0.13	0.13	0.02	0.02
Negro------------	0.77	0.57	*	0.19	0.52	0.36	*	0.20

Table 7. Prevalence of red-green color vision deficiencies among children 6-11 years of age, by subtype of defect, race, and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All red-green defects	Subtype			All red-green defects	Subtype		
		Protan	Deutan	Un-determined		Protan	Deutan	Un-determined
Both sexes	Rate per 100 children				Standard error			
Total------------	3.76	1.15	1.99	0.61	0.26	0.15	0.15	0.12
Boys								
Total------	6.88	2.15	3.85	0.87	0.48	0.30	0.29	0.16
White------------	7.36	2.40	4.16	0.79	0.49	0.33	0.32	0.15
Negro------------	4.04	0.68	1.96	1.39	1.24	0.39	1.13	0.71
Girls								
Total------	0.53	0.11	0.06	0.35	0.13	0.04	0.02	0.10
White------------	0.50	0.13	0.07	0.28	0.13	0.05	0.02	0.09
Negro------------	0.77	-	-	0.77	0.52	-	-	0.52

Table 8. Prevalence of red-green color vision deficiencies among children 6-11 years of age, by subtype of defect and severity, race, and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All red-green deficiencies	Protan				Deutan				Red-green undetermined			
		Total	Mild	Medium	Strong	Total	Mild	Medium	Strong	Total	Mild	Medium	Strong
	Rate per 100 children												
Both sexes													
Total	3.76	1.15	0.38	0.22	0.53	1.99	0.42	0.76	0.79	0.61	0.53	0.06	0.02
Boys													
Total	6.88	2.15	0.65	0.45	1.05	3.85	0.82	1.48	1.54	0.87	0.73	0.11	0.02
White	7.36	2.40	0.73	0.49	1.17	4.16	0.95	1.69	1.51	0.79	0.62	0.13	0.03
Negro	4.04	0.68	0.14	0.19	0.35	1.96	-	0.19	1.76	1.39	1.39	-	-
Girls													
Total	0.53	0.11	0.11	-	-	0.06	0.02	0.02	0.02	0.35	0.32	-	0.02
White	0.50	0.13	0.13	-	-	0.07	0.02	0.02	0.02	0.28	0.28	-	-
Negro	0.77	-	-	-	-	-	-	-	-	0.77	0.57	-	0.19
	Standard error												
Both sexes													
Total	0.26	0.15	0.07	0.06	0.10	0.15	0.06	0.09	0.12	0.12	0.12	0.02	0.01
Boys													
Total	0.48	0.30	0.13	0.12	0.20	0.29	0.11	0.19	0.24	0.16	0.17	0.05	0.02
White	0.49	0.33	0.15	0.12	0.22	0.32	0.13	0.22	0.19	0.15	0.15	0.06	0.03
Negro	1.24	0.39	0.17	0.20	0.25	1.13	-	0.20	1.14	0.71	0.71	-	-
Girls													
Total	0.13	0.04	0.04	-	-	0.02	0.02	0.02	0.02	0.10	0.08	-	0.02
White	0.13	0.05	0.05	-	-	0.02	0.02	0.02	0.02	0.09	0.09	-	-
Negro	0.52	-	-	-	-	-	-	-	-	0.52	0.36	-	0.20

Table 9. Prevalence of red-green color vision deficiencies among boys 6-11 years of age, by race and geographic region, with corresponding standard errors: United States, 1963-65

Geographic region	Total	White	Negro	Total	White	Negro
	Rate per 100 boys			Standard error		
United States----	6.88	7.36	4.04	0.48	0.49	1.24
Northeast-------------	8.52	8.98	4.88	1.08	1.12	2.72
Midwest---------------	6.18	6.25	5.63	1.06	1.00	4.08
South-----------------	6.05	7.43	2.60	0.42	0.57	1.57
West------------------	7.02	7.18	6.15	0.66	0.81	3.64

Table 10. Prevalence of red-green color vision deficiencies among children 6-11 years of age, by race, place of residence, and sex, with corresponding standard errors: United States, 1963-65

Place of residence and sex	Total	White	Negro	Total	White	Negro
Both sexes	Rate per 100 children			Standard error		
Total-----------------	3.76	3.99	2.41	0.26	0.27	0.75
Boys						
Total-----------------	6.88	7.36	4.04	0.48	0.49	1.24
Urban-----------------	6.51	7.08	3.77	0.56	0.65	1.26
Rural-----------------	7.59	7.86	5.09	0.86	0.85	2.72
Girls						
Total-----------------	0.53	0.50	0.77	0.13	0.13	0.52
Urban-----------------	0.39	0.37	0.48	0.10	0.13	0.35
Rural-----------------	0.79	0.71	1.95	0.28	0.26	2.30

Table 11. Prevalence of red-green color vision deficiencies among boys 6-11 years of age, by annual family income and race, with corresponding standard errors: United States, 1963-65

Race	All income groups	Annual family income: Less than $3,000	$3,000-$4,999	$5,000-$6,999	$7,000-$9,999	$10,000-$14,999	$15,000 or more	Unknown
	Rate per 100 boys							
Total	6.88	5.65	6.83	5.80	7.91	9.81	7.16	4.51
White	7.36	6.16	7.51	5.86	8.45	9.92	7.26	5.25
Negro	4.04	4.70	4.42	5.52	-	-	-	-
	Standard error							
Total	0.48	0.78	0.79	0.64	1.14	2.21	2.09	1.72
White	0.49	0.70	1.00	0.65	1.21	2.22	2.13	1.98
Negro	1.24	1.82	1.80	2.94	-	-	-	-

Table 12. Prevalence of blue-yellow color vision deficiencies among children 6-11 years of age, by severity of defect, race, and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All blue-yellow defects	Severity: Mild	Medium	Strong	All blue-yellow defects	Severity: Mild	Medium	Strong
	Rate per 100 children				Standard error			
Both sexes								
Total	0.36	0.30	0.02	0.03	0.08	0.07	0.01	0.02
Boys								
Total	0.53	0.46	0.02	0.04	0.15	0.14	0.02	0.03
White	0.57	0.49	0.03	0.05	0.16	0.16	0.03	0.03
Negro	0.30	0.30	-	-	0.28	0.28	-	-
Girls								
Total	0.18	0.13	0.02	0.02	0.04	0.04	0.02	0.02
White	0.16	0.13	0.03	-	0.05	0.03	0.03	-
Negro	0.34	0.15	-	0.19	0.28	0.17	-	0.20

Table 13. Prevalence of blue-yellow color vision deficiencies among children 6-11 years of age, by subtype of defect, race, and sex, with corresponding standard errors: United States, 1963-65

Race and sex	All blue-yellow defects	Subtype			All blue-yellow defects	Subtype		
		Tritan	Tetartan	Undetermined		Tritan	Tetartan	Undetermined
	Rate per 100 children				Standard error			
Both sexes								
Total	0.36	0.30	0.03	0.02	0.08	0.07	0.02	0.01
Boys								
Total	0.53	0.46	0.04	0.02	0.15	0.14	0.03	0.02
White	0.57	0.49	0.05	0.03	0.16	0.16	0.03	0.03
Negro	0.30	0.30	-	-	0.28	0.28	-	-
Girls								
Total	0.18	0.13	0.02	0.02	0.04	0.04	0.02	0.02
White	0.16	0.13	0.03	-	0.05	0.03	0.03	-
Negro	0.34	0.15	-	0.19	0.28	0.17	-	0.20

Table 14. Prevalence of color vision deficiencies involving both red-green and blue-yellow perception among children 6-11 years of age, by race and sex, with corresponding standard errors: United States, 1963-65

Race	Both sexes	Boys	Girls	Both sexes	Boys	Girls
	Rate per 100 children			Standard error		
Total	0.32	0.46	0.18	0.08	0.14	0.04
White	0.33	0.49	0.16	0.09	0.16	0.05
Negro	0.32	0.30	0.34	0.19	0.28	0.28

APPENDIX I

STATISTICAL NOTES

The Survey Design

The sample design for the second cycle of the Health Examination Survey, similar to the one used for the first cycle, was that of a multistage, stratified probability sample of loose clusters of persons in land-based segments. Successive elements dealt with in the process of sampling are primary sampling unit (PSU), census enumeration district (ED), segment, household, eligible child (EC), and, finally, the sample child (SC).

At the first stage, the nearly 2,000 PSU's into which the United States (including Hawaii and Alaska) has been divided and then grouped into 357 strata for use in the Current Population Survey and the Health Interview Survey were further grouped into 40 superstrata for use in Cycle II of the Health Examination Survey. The average size of each Cycle II stratum was 4.5 million persons, and all strata fell between the limits of 3.5 and 5.5 million. Grouping into 40 strata was done in a way that maximized homogeneity of the PSU's included in each stratum, particularly with regard to degree of urbanization, geographic proximity, and degree of industrialization. The 40 strata were classified into four broad geographic regions (each with 10 strata) of approximately equal population and cross-classified into four broad population density groups (each having 10 strata). Each of the 16 cells contained either two or three strata. A single stratum might include only one PSU, only part of a PSU (e.g., New York City, which represented two strata), or several score PSU's.

To take account of the possible effect that the rate of population change between the 1950 and 1960 Census might have had on health, the 10 strata within each region were further classified into four classes ranging from those with no increase to those with the greatest relative increase. Each such class contained either two or three strata.

One PSU was then selected from each of the 40 strata. A controlled selection technique was used in which the probability of selection of a particular PSU was proportional to its 1960 population. In the controlled selection an attempt was also made to maximize the spread of the PSU's among the States. While not every one of the 64 cells in the 4x4x4 grid contributes a PSU to the sample of 40 PSU's, the controlled selection technique ensured the sample's matching the marginal distributions in all three dimensions and being closely representative of all cross-classifications.

Generally, within a particular PSU, 20 ED's were selected with the probability of selection of a particular ED proportional to its population in the age group 5-9 years in the 1960 Census, which by 1963 roughly approximated the population in the target age group for Cycle II. A similar method was used for selecting one segment (cluster of households) in each ED. Each of the resultant 20 segments was either a bounded area or a cluster of households (or addresses). All the children in the age range properly resident at the address visited were EC's. Operational considerations made it necessary to reduce the number of prospective examinees at any one location to a maximum of 200. The EC's to be excluded for this reason from the SC group were determined by systematic subsampling.

The total sample included 7,417 children from 25 different States in the age group 6-11 years with approximately 1,000 in each of the single years of age.

Reliability

Measurement processes employed in the survey were highly standardized and closely controlled. Of course this does not mean that the correspondence between the real world and the survey results is exact. Data from the survey are imperfect for three major reasons: (1) results are subject to sampling error, (2) the actual conduct of a survey never agrees perfectly with the design, and (3) the measurement processes themselves are inexact even though standardized and controlled.

The first report on Cycle II[6] describes in detail the faithfulness with which the sampling design was carried out. It notes that out of the 7,417 sample children the 7,119 who were examined—a response rate of 96 percent—gave evidence that they were a highly representative sample of children of this age in the noninstitutional population of the United States. The response levels for the various demographic subgroups—including those for age, sex, race, region, population density, parent's education level, and family income—show no marked differentials. Hence it appears unlikely that nonresponse could bias the findings much in these respects.

Measures used to control the quality of data from this survey in general have been cited previously;[6] those relating specifically to the vision tests are outlined in an earlier section of this report.

Data recorded for each sample child are inflated in the estimation process to characterize the larger universe of which the sample child is representative. The weights used in this inflation process are a product of the reciprocal of the probability of selecting the child, an adjustment for nonresponse cases, and a poststratified ratio adjustment which increases precision by bringing survey results into closer alignment with known U.S. population figures by color and sex within single years of age 6-11.

In the second cycle of the Health Examination Survey, the sample was the result of three stages of selection—the single PSU from each stratum, the 20 segments from each sample PSU, and the sample children from the eligible children. The probability of selecting an individual child is the product of the probability of selection at each stage.

Since the strata are roughly equal in population size and a nearly equal number of sample children were examined in each of the sample PSU's, the sample design is essentially self-weighting with respect to the target population; that is, each child 6-11 years of age had about the same probability of being drawn into the sample.

The adjustment upward for nonresponse is intended to minimize the impact of nonresponse on final estimates by imputing to nonrespondents the characteristics of "similar" respondents. Here "similar" respondents were judged to be examined children in a sample PSU having the same age (in years) and sex as children not examined in that sample PSU.

The post stratified ratio adjustment used in the second cycle achieved most of the gains in precision which would have been attained if the sample had been drawn from a population stratified by age, color, and sex and made the final sample estimates of population agree exactly with independent controls prepared by the Bureau of the Census for the noninstitutional population of the United States as of August 1, 1964 (approximate midsurvey point), by color and sex for each single year of age 6-11. The weight of every responding sample child in each of the 24 age, color, and sex classes is adjusted upward or downward so that the weighted total within the class equals the independent population control.

Sample frequencies and estimated population frequencies as of the approximate midsurvey point are shown by age, sex, and race in table I.

Table I. Sample and estimated population frequency distribution of children in the noninstitutional population of the United States, by race, age, and sex: Health Examination Survey 1963-65

Age and sex	Number of Children in sample				Estimated number of children in population			
	Total	White	Negro	Other races	Total	White	Negro	Other races
Both sexes					*In thousands*			
6-11 years . . .	7,119	6,100	987	32	23,784	20,403	3,271	109
Boys								
6-11 years . .	3,632	3,153	464	15	12,080	10,390	1,642	47
6 years	575	489	84	2	2,081	1,787	289	5
7 years	632	551	79	2	2,073	1,780	286	6
8 years	618	537	79	2	2,026	1,739	279	7
9 years	603	525	74	4	2,011	1,729	268	13
10 years	576	509	65	2	1,963	1,692	264	6
11 years	628	542	83	3	1,923	1,661	254	7
Girls								
6-11 years . .	3,487	2,947	523	17	11,703	10,012	1,629	61
6 years	536	461	72	3	2,016	1,722	280	13
7 years	609	512	93	4	2,010	1,716	283	10
8 years	613	498	113	2	1,960	1,674	280	5
9 years	581	494	84	3	1,945	1,663	265	16
10 years	584	505	77	2	1,904	1,632	265	6
11 years	564	477	84	3	1,868	1,605	252	10

Sampling and Measurement Error

In the present report, reference has been made to efforts to minimize bias and variability of measurement techniques.

The probability design of the survey makes possible the calculation of sampling errors. The sampling error is used here to determine how imprecise the survey test results may be because they come from a sample rather than from the measurements of all elements in the universe.

The estimation of sampling errors for a study of the type of the Health Examination Survey is difficult for at least three reasons: (1) measurement error and "pure" sampling error are confounded in the data—it is not easy to find a procedure which will either completely include both or treat one or the other separately, (2) the survey design and estimation procedure are complex and accordingly require computationally involved techniques for the calculation of variances, and (3) from the survey are coming thousands of statistics, many for subclasses of the population for which there are a small number of cases. Estimates of sampling error are obtained from the sample data and are themselves subject to sampling error which may be large when the number of cases in a cell is small or even occasionally when the number of cases is substantial.

Estimates of approximate sampling variability for selected statistics used in this report are presented in the detailed tables. These estimates have been prepared by a replication technique which yields overall variability through observation of variability among random subsamples of the total sample. The method reflects both "pure" sampling variance and a part of the measurement variance.

In accordance with usual practice, the interval estimate for any statistic may be considered the range within one standard error of the tabulated statistic, with 68 percent confidence, or the range within two standard errors of the tabulated statistic with 95-percent confidence. The latter is used as the level of significance in this report.

An approximation of the standard error of a difference $d = x - y$ of two statistics x and y is given by the formula $S_d = (S_x^2 + S_y^2)^{1/2}$ where S_x and S_y are the sampling errors, respectively, of x and y.

Small Categories

In some tables magnitudes are shown for cells for which the sample size is so small that the sampling error may be several times as great as the statistic itself. Obviously, in such instances the statistic has no meaning in itself except to indicate that the true quantity is small. Such numbers, if shown, have been included in the belief that they may help to convey an impression of the overall story of the table.

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APPENDIX II

DEMOGRAPHIC TERMS

Age.—The age recorded for each child was the age at last birthday on the date of examination. The age criterion for inclusion in the sample used in this survey was defined in terms of age at time of interview. Since the examination usually took place 2 to 4 weeks after the interview, some of those who were 11 years old at the time of interview became 12 years old by the time of the examination. There were 72 such cases. In the adjustment and weighting procedures used to produce national estimates, these 72 were included in the 11 year old group.

Race.—Race was recorded as "white," "Negro," or "other." The last category included American Indians, Chinese, Japanese. and all races other than white or Negro. Persons of Mexican descent were included with "white" unless definitely known to be American Indian or of another race. Negroes and persons of mixed Negro and other parentage were recorded as "Negro."

Family Income.—The income recorded was the total income received during the past 12 months by the head of the household and all other household members related to the head by blood, marriage, or adoption. This income was the gross cash income (excluding pay in kind, e.g., meals, living quarters, or supplies provided in place of cash wages) except in the case of a family with its own farm or business, in which case net income was recorded.

Place of Residence.—The definition of urban and rural areas was the same as that used in the 1960 Census. According to this definition, the urban population was comprised of all persons living in (a) places of 2,500 inhabitants or more incorporated as cities, boroughs, villages, and towns (except towns in New England, New York, Wisconsin); (b) the densely settled urban fringe, whether incorporated or unincorporated, of urbanized areas; (c) towns in New England and townships in New Jersey and Pennsylvania which contained no incorporated municipalities as subdivisions and had either 2,500 inhabitants or more, or a population of 2,500 to 25,000 and a density of 1,500 persons or more per square mile; (d) counties in States other than the New England States, New Jersey, and Pennsylvania that had no incorporated municipalities within their boundaries and had a density of 1,500 persons or more per square mile; (e) unincorporated places of 2,500 inhabitants or more not included in any urban fringe. The remaining population was classified as rural.

Geographic Region.—For purposes of stratification the United States was divided into four broad geographic regions of approximately equal population. These regions, which correspond closely to those used by the U.S. Bureau of the Census, are as follows:

Region	*States Included*
Northeast	Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania
Midwest	Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, and Missouri

Region	*States Included*
South	Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and Arkansas
West	Washington, Oregon, California, Nevada, New Mexico, Arizona, Texas, Oklahoma, Kansas, Nebraska, North Dakota, South Dakota, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii

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APPENDIX III

RECORDING SHEETS USED FOR COLOR VISION TESTING

HEALTH EXAMINATION SURVEY—II

VISION

EXAMINER	NO REPORT

Wears glasses for test: ☐ Yes ☐ No

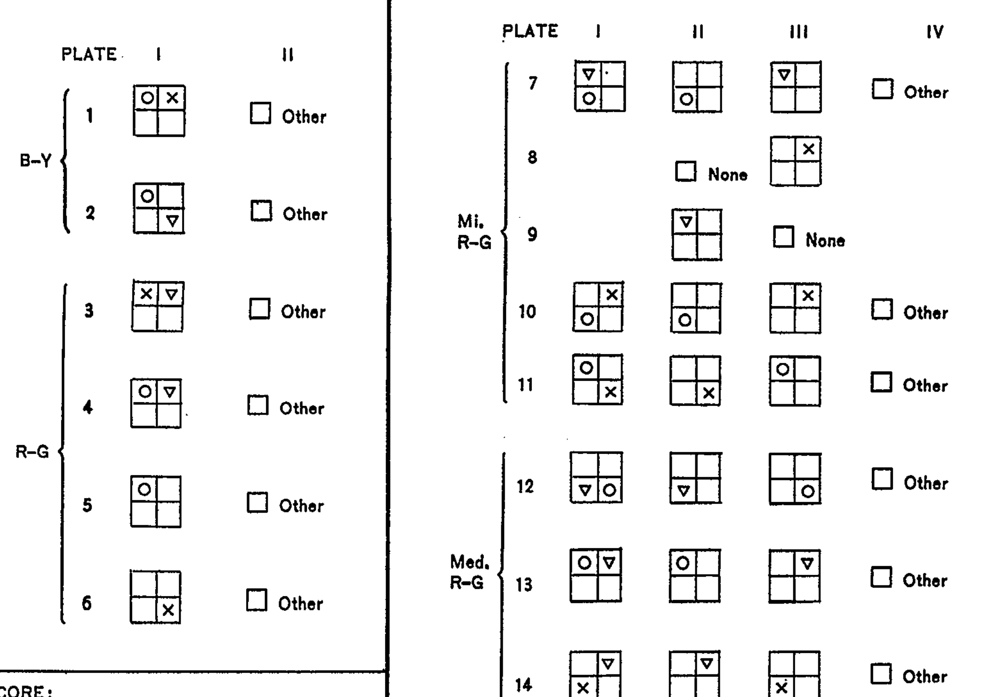
COLOR VISION TEST NO. 1—Ishihara binocular test (with glasses if worn)

PLATE	READ AS		PLATE	READ AS	
1	☐ 12	☐ Other	14	☐ Other	☐ 5
2	☐ 8	☐ 3 ☐ Other	16	☐ 42	☐ 2 ☐ 42
5	☐ 5	☐ 2 ☐ Other			☐ 4 ☐ 42
8	☐ 2	☐ Other			☐ Other
11	☐ 5	☐ Other	SCORE:*		

**Exclude plate 1 in scoring. Score=number answered correctly. Omit Color Vision Test Number 2 (H-R-R) if score=6.*

COLOR VISION TEST NUMBER 2—H-R-R (Check reply given for each plate)

VISION 1



SCORE:
(1 through 6) ....

PHS—4611-6 (PAGE 1)
2-64

SAMPLE NO. (1-6)

COLOR VISION TEST NO. 2—H-R-R (Continued)

	PLATE	I	II	III	IV
Str. R-G	15	X, O	X	O	☐ Other
	16	O, ▽	O	▽	☐ Other

SCORE: (7 through 16) ....

	PLATE	I	II	III	IV
Med. B-Y	17	X, ▽	▽	X	☐ Other
	18	O, X	X	O	☐ Other
Str. B-Y	19	O, ▽	O	▽	☐ Other
	20	X, ▽	▽	X	☐ Other

SCORE: (17 through 20) ....

SCREENING SERIES (Plates 1–6)

☐ Normal (Score col. I=6)

☐ R–G abnormal (Check(s) in col. II, pl. 3–6)

☐ B–Y abnormal (Check(s) in col. II, pl. 1–2)

DIAGNOSTIC SERIES (Plates 7–20)

TYPE: ☐ Protan (Score col. II>col. III, pl. 7–16)

☐ Deutan (Score col. III>col. II, pl. 7–16)

☐ Tritan (Score col. II>col. III, pl. 17–20)

☐ Tetartan (Score col. III>col. II, pl. 17–20)

DEGREE: ☐ Mild (Check(s) in col. II, pl. 1 or 2 but none in col. II or III, pl. 17–20; or, check(s) in col. II or III, pl. 7–11 but none in col. II or III, pl. 12–16) 2

☐ Moderate (Check(s) in col. II or III, pl. 17–18 but none in col. II or III, pl. 19–20; or check(s) in col. II or III, pl. 12–14 but none in col. II or III, pl. 15–16)

☐ Severe (Check(s) in col. II or III, pl. 19–20; or check(s) in col. II or III, pl. 15–16)

Score comparison (7–16): Code ....

Score comparison (17–20): Code ....

Type and severity of color deficiency from Test No. 2 ....

PHS–4611–6 (PAGE 2)
2-64

SAMPLE NO.

——— ooo ———

APPENDIX IV

FREQUENCY DISTRIBUTIONS OF CHILDREN WITH BOTH RED-GREEN AND BLUE-YELLOW COLOR VISION DEFICIENCIES

Frequency distribution of children found in the examination to have specific combinations of both red-green and blue-yellow color vision deficiencies are presented by sex in table II.

Among 17 boys so affected, all showed evidence of mild tritan type deficiencies in combination with red-green defects, the most frequent one being of the strong deutan type.

Of seven girls diagnosed as having color vision deficiencies involving both red-green and blue-yellow perception, five showed mild tritan type deficiencies associated with mild red-green defects undetermined as to type. One girl showed a medium tetartan type defect associated with a mild red-green defect undetermined as to type, and another showed evidence of a strong red-green defect and a strong blue-yellow defect, both undetermined as to type.

The most frequent combination of deficiences among both sexes was mild red-green undetermined as to type associated with a mild tritan type defect.

Table II. Frequency distribution of children 6-11 years of age with both red-green and blue-yellow color vision deficiencies, by diagnosis and sex: Health Examination Survey, 1963-65

Deficiency and sex		Protan			Deutan			Red-green, type undetermined		
		Mild	Medium	Strong	Mild	Medium	Strong	Mild	Medium	Strong
Both sexes (24 cases)										
Tritan	Mild	1	1	3	2	1	6	8	—	—
	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	—
Tetartan	Medium	—	—	—	—	—	—	1	—	—
	Strong	—	—	—	—	—	—	—	—	—
Undetermined	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	1
Boys (17 cases)										
Tritan	Mild	1	1	3	2	1	6	3	—	—
	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	—
Tetartan	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	—
Undetermined	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	—
Girls (7 cases)										
Tritan	Mild	—	—	—	—	—	—	5	—	—
	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	—
Tetartan	Medium	—	—	—	—	—	—	1	—	—
	Strong	—	—	—	—	—	—	—	—	—
Undetermined	Medium	—	—	—	—	—	—	—	—	—
	Strong	—	—	—	—	—	—	—	—	1

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