

# PSEUDOISOCROMATIC CHARTS

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## PSEUDOISCHROMATIC CHARTS

**Primary Disciplinary Field(s):** Ophthalmology, Optometry, Visual Perception

### 1. Core Definition and Function

**Pseudoisochromatic charts** (PICs) represent a crucial class of standardized diagnostic instruments utilized extensively in clinical settings to screen for congenital and acquired deficiencies in **color vision**, commonly referred to as **color blindness** (CVD). The operational success of these charts rests upon the principle of pseudoisochromatism, which translates literally to "falsely equal colors." These tests are constructed using intricate patterns--typically composed of numbers, symbols, or meandering paths--formed by dots of varying sizes and chromaticity. The colors of the figure and the background are meticulously calibrated such that an individual possessing normal trichromatic vision can effortlessly distinguish the embedded pattern due to differences in hue. Conversely, an individual suffering from specific forms of color vision deficiency, such as common red-green defects, perceives the figure and the ground as having nearly identical luminance and color saturation, effectively rendering the hidden image ambiguous or completely invisible.

The fundamental mechanism by which PICs function involves exploiting the spectral response characteristics of the cone photoreceptors in the human retina. Normal color perception is dependent upon the accurate differential signaling from the three types of cones (Short-wavelength, Medium-wavelength, and Long-wavelength sensitive cones). In the case of protanopia or deuteranopia--the predominant forms of red-green CVD--the reduced or altered sensitivity of the L-cones (protan defects) or M-cones (deutan defects) results in a collapse of discrimination along the red-green color axis. The colors selected for the PIC plates fall along the observer's specific axis of color confusion. Thus, the test provides a rapid and objective means to assess whether an observer can successfully differentiate between specific wavelength pairs that present difficulty for defective cone systems, thereby confirming the presence of a deficiency.

A key engineering constraint in the design of effective PICs is the rigorous control over **luminance**, or perceived brightness. If the figure and background dots differed significantly in brightness, even a severely color-deficient observer could utilize these intensity cues to outline the pattern, negating the test's purpose. Therefore, sophisticated printing techniques are employed to ensure the chromatic differences are isolated from luminance differences. The observer's successful recognition of the pattern must rely solely on the integration of chromatic information, making PICs highly specific diagnostic tools for evaluating the functional integrity of the cone photopigments.

### 2. Etymology and Historical Development

The etymological roots of **pseudoisochromatic** reveal its function: derived from Greek, *pseudo-* (false), *iso-* (equal), and *chroma* (color), the term accurately describes a situation where colors are falsely equated by the deficient visual system. Historically, the assessment of color vision deficiencies was rudimentary and highly subjective, often relying on tasks such as the matching of colored wool skeins, famously exemplified by the Holmgren test. While useful for gross screening, these older methods lacked the standardization and quantitative precision necessary for reliable clinical diagnosis and occupational screening.

The standardization of color vision testing was fundamentally transformed by the introduction of the first widely accepted set of PICs in 1917 by Dr. Shinobu Ishihara, a Japanese ophthalmologist. Recognizing the urgent need for a dependable, easy-to-administer screening tool--especially for military personnel and railway workers where color discrimination is critical for safety--Dr. Ishihara devised his iconic plates. These plates systematically used dot matrices printed with specific spectral colors that exploited the known confusion axes of red-green deficiencies. The **Ishihara test** quickly achieved global acceptance, establishing the paradigm for all subsequent pseudoisochromatic testing methodologies due to its high reliability and simplicity in screening for congenital red-green color blindness.

While the Ishihara test remains the benchmark for red-green screening, its limitations--primarily its inability to diagnose tritan (blue-yellow) deficiencies or accurately grade severity--led to the development of more advanced PIC systems. A notable successor was the **Hardy-Rand-Rittler (HRR) plates**, introduced in the 1940s. The HRR plates expanded the diagnostic scope by incorporating specialized plates designed to screen for all three major congenital CVD types (Protan, Deutan, and Tritan) and employing geometric symbols to aid in diagnosis. Furthermore, the HRR system attempted to provide a rudimentary categorization of the severity of the defect (mild, medium, or severe), offering a more granular diagnostic output than the binary pass/fail results typical of the standard Ishihara charts.

### 3. Mechanism of Pseudoisochromatism and Plate Construction

The construction of an effective PIC plate is an exercise in applied colorimetry and visual perception. Each plate is meticulously printed, ensuring that the figure (the embedded pattern) and the ground (the surrounding field) are composed of dots whose specific spectral reflectances are chosen to align with the confusion locus of the target deficiency. The selection of inks is critical; they must provide high saturation color differences for normal observers, yet appear maximally confusable when viewed through the spectral filtering of defective cone systems.

The technique relies heavily on the principle of **isochromatic confusion**, where the stimulus colors are chosen so that they project onto the same point on the specific color-deficient observer's internal representation of color space. For instance, a plate targeting protanopes might utilize a

purplish-red for the figure and a grayish-green for the background. These two colors reflect light across the spectrum in a manner that produces virtually identical output signals from the L-cones of a protanope, thus making the figure indistinguishable from the background. Crucially, the pigments used must also minimize any secondary brightness differences that could otherwise provide a perceptual shortcut.

A key characteristic of all reliable PICs is the use of a **dot matrix construction**, rather than solid colored areas. This strategy, sometimes termed **spatial frequency masking**, involves randomizing the size, shape, and spatial distribution of the dots composing the pattern. This deliberate heterogeneity serves to prevent the observer from detecting the figure via cues related to visual acuity, edge detection, or spatial contrast. Instead, the task forces the observer to rely on the integration of purely chromatic signals across the visual field, ensuring that the diagnosis is based strictly on color discrimination ability mediated by the cone system.

#### 4. Key Characteristics of Standard PICs

**Standardized Illumination Requirements:** The spectral characteristics of the light source are critical. PICs must be administered under strictly controlled lighting conditions, typically specified as **CIE Standard Illuminant C** or D65 (simulated daylight, 6500 K). Using ambient room light, especially warm incandescent lamps, shifts the spectral balance of the reflected light, potentially destroying the carefully engineered luminance equivalence and invalidating the test results, often resulting in inaccurate false negatives.

**Chromatic Confusion Pairs:** PICs are characterized by their use of highly saturated, specific color pairs that lie precisely along the known **color confusion lines** for the targeted deficiency (e.g., the red-green axis for Protan/Deutan, or the blue-yellow axis for Tritan). The specific hues are selected to maximize the difference for a normal observer while minimizing the difference for a deficient observer.

**Vanishing and Transformation Plates:** Most comprehensive PIC sets include specific plate types to differentiate the diagnosis. **Vanishing plates** contain figures visible only to normal observers and invisible to those with CVD. **Transformation plates** display one figure to normal observers and a different, visible figure to those with CVD, aiding in the differentiation between protan and deutan types.

**Print Longevity and Integrity:** Because the validity of the test relies entirely on the precise spectral properties of the printed colors, PICs are sensitive to pigment degradation over time. Exposure to sunlight, humidity, and atmospheric pollutants can cause the inks to fade or shift, compromising the luminance and chromatic matching. Consequently, regulatory bodies often recommend the replacement of paper-based PICs at defined intervals (e.g., every five to ten years).

## 5. Clinical Administration and Methodology

The strict adherence to standardized methodology is necessary to ensure the reliability and comparative validity of pseudoisochromatic testing results across different clinical settings. Patients are typically positioned at a reading distance of 75 centimeters (approximately 30 inches) from the chart, consistent with standard clinical visual testing protocols. The test plates must be presented perpendicular to the line of sight, usually one at a time, to minimize distraction and ensure uniform illumination across the surface.

Time limitation is a crucial component of PIC administration. Each plate should be exposed for a brief, fixed period, usually between 3 and 5 seconds. This constraint is purposefully enforced to prevent the observer from undertaking extended visual scrutiny, which might allow them to identify the figure based on subtle non-chromatic cues, such as minute variations in paper texture, dot density, or unintended luminance artifacts. This rapid presentation ensures that the judgment is based on an immediate, integrated chromatic perception.

Scoring involves recording the observer's verbal identification of the figure (or tracing of the path for path-following charts). The total number of missed plates determines whether a deficiency is present. In tests like the Ishihara, specific patterns of missed plates (e.g., reading 6 instead of 8 on a transformation plate) allow the clinician to tentatively classify the deficiency as either protan (red-weak) or deutan (green-weak). For non-verbal or pre-literate patients, specialized charts featuring universal symbols, geometric shapes, or tracing paths are utilized, maintaining the pseudoisochromatic principle while adapting to the patient's cognitive capabilities.

## 6. Significance in Occupational Health and Safety

Pseudoisochromatic charts hold immense significance in the domains of occupational medicine, public safety, and transportation regulation. Accurate color vision is a prerequisite for numerous safety-critical professions where the rapid and reliable discrimination of signals, markers, and indicators is non-negotiable. Examples include pilots, air traffic controllers, railway engineers, maritime navigators, electrical workers dealing with color-coded wiring, and military personnel.

Regulatory bodies worldwide mandate the use of standardized PIC tests, such as the Ishihara or HRR, during initial licensing and periodic medical assessments for these professions. For instance, global aviation authorities require applicants to demonstrate normal or near-normal color vision using these standardized tests to ensure they can correctly interpret critical cockpit displays, navigational lights, and runway signals, where errors resulting from CVD could have catastrophic consequences. Failure to pass the initial PIC screening typically necessitates follow-up with more rigorous, quantitative color vision tests, such as anomaloscopy, before final fitness decisions can be made.

Furthermore, the widespread adoption of PICs has facilitated large-scale epidemiological studies into the prevalence and genetic underpinnings of color vision deficiencies. Since congenital CVD is largely sex-linked, affecting approximately 8% of males of Northern European descent and 0.5% of females, these screening tools provide vital public health data that inform educational planning, career counseling, and the design of color-coded systems in public infrastructure and communication.

## 7. Limitations and Diagnostic Ambiguity

While essential for screening, PICs are not definitive diagnostic tools for all aspects of color vision. Their primary limitation is their nature as qualitative screening tests, meaning they determine the presence and type of CVD but generally lack the precision to accurately quantify the severity of the defect, particularly in cases of **anomalous trichromacy**--where the cones are present but functioning abnormally--as opposed to the complete absence of a cone type (dichromacy). For determining the precise degree of deficiency, quantitative instruments like the Farnsworth-Munsell 100 Hue Test or the Nagel anomaloscope are required.

Another significant source of potential error lies in the detection of **tritanopia** (blue-yellow deficiency). While specialized PICs like the HRR plates include plates designed to test this deficiency, the sensitivity and specificity for tritan defects are generally acknowledged to be lower than those for red-green defects. Tritan defects are rarer and often associated with acquired conditions (such as optic nerve disease or certain medications), requiring a broader differential diagnosis than simple congenital screening can provide.

Finally, results from PICs can be compromised by factors external to the patient's vision. Poor test administration, particularly the use of incorrect illumination (e.g., fluorescent or incandescent light), is the single largest cause of **false negative results**. Additionally, the physical deterioration of the charts themselves due to fading ink or smudging can compromise the delicate chromatic balance required for the pseudoisochromatic effect. Clinicians must therefore ensure rigorous adherence to procedural standards and routine replacement of test materials to maintain high diagnostic accuracy.

## Further Reading

[Ishihara Test \(Wikipedia\)](#)

[Color Blindness \(Wikipedia\)](#)

[Hardy, Rand, and Rittler Plates \(Wikipedia\)](#)

[Optometry \(Wikipedia\)](#)