Title
The Role of Subtractive Color Mixing in the Perception of Blue Nevi and Veins—Beyond the Tyndall Effect

Journal
JAMA Dermatology, 152(10)

ISSN
2168-6068

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Publication Date
2016-10-01

DOI
10.1001/jamadermatol.2016.2201

Peer reviewed

Letters

RESEARCH LETTER

The Role of Subtractive Color Mixing in the Perception of Blue Nevi and Veins—Beyond the Tyndall Effect

The original study[1] that proposed the "Tyndall effect" as the explanation behind the coloration of blue nevi drew from spectrophotometric data on cadaveric skin and not the direct study of blue nevi. Since then, the moniker of the Tyndall effect has been applied to a variety of blue phenomena in the skin despite a lack of confirmatory data. We hypothesized that other light-skin optical characteristics may provide a better explanation for the visual phenomenon associated with why blue nevi appear blue.

To briefly review the optics of the skin, perceived color is produced by light that strikes the skin and is remitted (a combination of light reflected and scattered back to the eye). The epidermis plays a minimal role in scattering, responsible primarily for the baseline reflectance of 5% to 7% of light from the skin surface.[2] The Tyndall effect originally described the preferential scattering of shorter wavelength blue light through particulate matter in air and fluids, and its application to solid tissue optics is based on extrapolative hypotheses. Accordingly, such scattering would occur in a homogenous manner diffusely throughout the skin, not only in blue nevi, which led us to believe that the Tyndall effect does not fully account for the optics associated with blue nevi and veins.

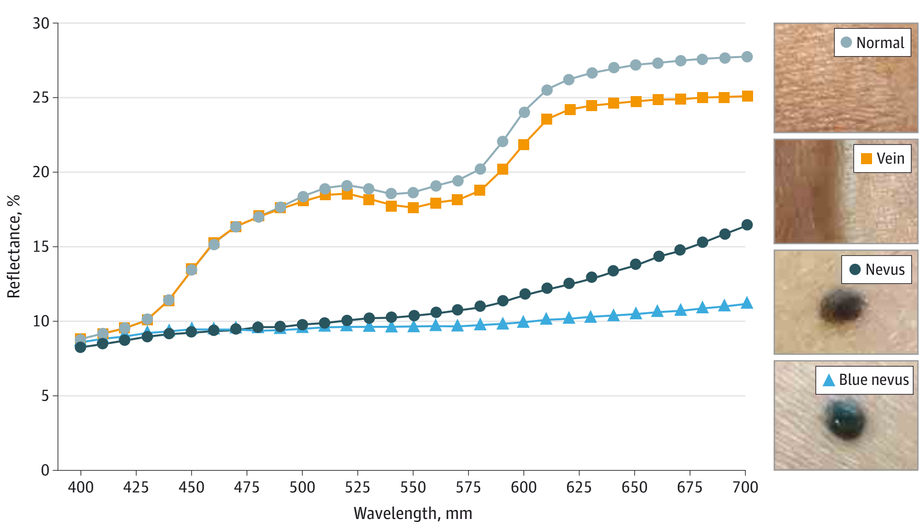
Methods | We used a spectrophotometer (Konica-Minolta CM 2600d) to measure reflectance from (1) a normal and blue nevus and (2) a vein and comparable normal skin—each pair from the same authors. Telephone consultation with the Western Institutional Review Board (WIRB), Puyallup, Washington, determined this research to be exempt and institutional review board review was waived.

Results | Both types of nevi showed reflectance spectra similar to known melanin curves—with high absorption of blue light and decreased absorption of red light (**Figure 1**).[2] The shorter wavelengths (approximately 400-500 nm) demonstrated the expected baseline reflectance off of the surface of the skin (8%), illustrating that the role of blue light scattering is minimal, and the amount of red-spectrum light is the main determinant of color. The spectral curves between vein skin and normal skin demonstrated similar decrease in red in the skin overlying a vein.

Discussion | The decrease in red light that yields the blue appearance of nevi and veins is accounted for through a concept termed "subtractive color mixing," analogous to removing red out of purple paint.[3] While the distinction between preferential blue scattering (Tyndall effect) or less red reflectance initially appears semantic, it recognizes that there are additional reasons beyond light scatter that can lead to decreased red reflectance, including differences in vasculature, hemoglobin levels, or characteristics of melanin (small structural differences can lead to changes in color, as seen in oxyhemoglobin vs deoxyhemoglobin).

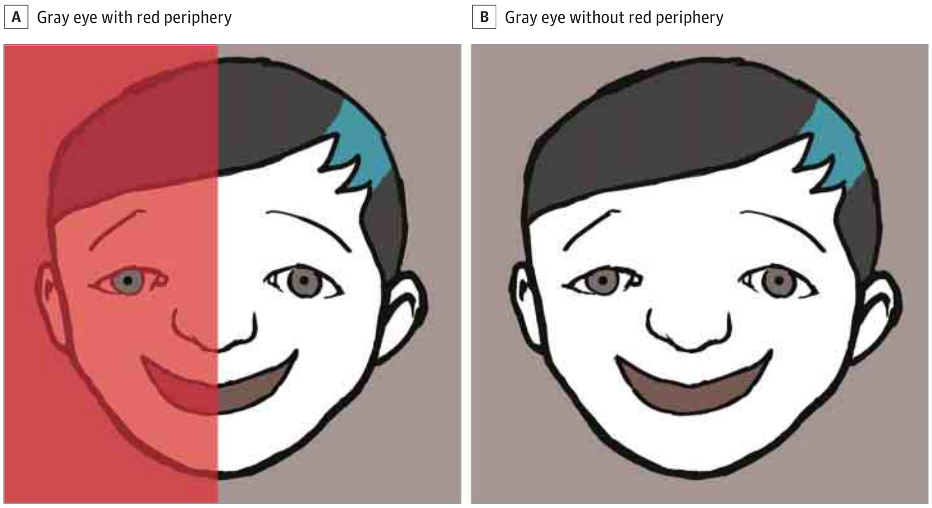
In veins, the decrease in red color prompts a change in color perception.[4,5] In this situation, the eye uses a type of chromatic induction called "simultaneous contrast" to enhance the contrast between 2 colors, leading the brain to perceive and

Figure 1. Reflectance Spectra of Normal Skin, Skin Overlying a Vein, a Normal Nevus, and a Blue Nevus



This graph shows the reflectance of a blue nevus, nevus, normal skin, and a vein across a spectrum of visible light ranging from 400 nm to 700 nm. The blue nevus shows a decreased red light reflectance compared with a normal nevus, and the vein shows a decreased red light reflectance compared with normal skin. Through the concept of subtractive color mixing, this decrease in red light contributes to a perceived blue hue.

Figure 2.Image Depicting the Concept of Simultaneous Contrast



This image demonstrates the concept of simultaneous contrast. Both eyes in A and B are exactly the same hue of gray (CMYK 55%, 53%, 48%, 16%). A, When 1 eye is peripherally surrounded by red, that same gray hue appears dramatically blue. B, This illusion is dispelled when the red is removed. Image adapted from Rootman et al.[4]

interpret this lack of red as blue.[4,6] The principle is illustrated in **Figure 2**A, where both eyes are exactly the same hue of gray (CMYK 55%, 53%, 48%, 16%), but when 1 eye is peripherally surrounded by red, that same gray hue appears strikingly blue. This illusion is dispelled when the surrounding red is removed (Figure 2B).

It is traditionally explained that the Tyndall effect leads to a preferential scattering and subsequent reflectance of blue light back to the eye, which accounts for the color of blue nevi. Blue nevi and veins are perceived as blue because they have less red, leading to a shift in hue toward blue (subtractive color mixing), an effect enhanced by chromatic induction because of the decrease in red relative to the surrounding skin.

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Published Online: July 13, 2016. doi:10.1001/jamadermatol.2016.2201.

Author Contributions: Drs Shive and Jagdeo had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Shive, Ho, Mamalis, Jagdeo.
Acquisition, analysis, or interpretation of data: Shive, Ho, Lai, Mamalis, Miller, Jagdeo.
Drafting of the manuscript: Shive, Jagdeo.
Critical revision of the manuscript for important intellectual content: Shive, Ho, Mamalis, Miller, Jagdeo.

Conflict of Interest Disclosures: None reported.

Additional Contributions: We are indebted to Randy Bunney, BS, Konica-Minolta, for his help with the data collection. He was not compensated for his contribution.

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