Inter-individual variations in color naming and the structure of 3D color space

Jordi Roca-Vila, A. Owen, G. Jordan, Y. Ling, C. Alejandro Parraga, A. Hurlbert

Many everyday behavioural uses of color vision depend on color naming ability, which is neither measured nor predicted by most standardized tests of color vision, for either normal or anomalous color vision. Here we demonstrate a new method to quantify color naming ability by deriving a compact computational description of individual 3D color spaces. Methods: Individual observers underwent standardized color vision diagnostic tests (including anomaloscope testing) and a series of custom-made color naming tasks using 500 distinct color samples, either CRT stimuli (“light”-based) or Munsell chips (“surface”-based), with both forced- and free-choice color naming paradigms. For each subject, we defined his/her color solid as the set of 3D convex hulls computed for each basic color category from the relevant collection of categorised points in perceptually uniform CIELAB space. From the parameters of the convex hulls, we derived several indices to characterise the 3D structure of the color solid and its inter-individual variations. Using a reference group of 25 normal trichromats (NT), we defined the degree of normality for the shape, location and overlap of each color region, and the extent of “light”-“surface” agreement. Results: Certain features of color perception emerge from analysis of the average NT color solid, e.g.: (1) the white category is slightly shifted towards blue; and (2) the variability in category border location across NT subjects is asymmetric across color space, with least variability in the blue/green region. Comparisons between individual and average NT indices reveal specific naming “deficits”, e.g.: (1) Category volumes for white, green, brown and grey are expanded for anomalous trichromats and dichromats; and (2) the focal structure of color space is disrupted more in protanopia than other forms of anomalous color vision. The indices both capture the structure of subjective color spaces and allow us to quantify inter-individual differences in color naming ability.