THE UNDERLYING DIMENSIONS OF SOUND-COLOR CORRESPONDENCES REVEAL TYPOLOGICALLY AND EVOLUTIONARILY GROUNDED LINGUISTIC PRIMITIVES

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Color plays a crucial role in language as it signals anything from danger and emotions to political affiliations, and most people have strong, sometimes synesthetic associations between colors and sounds. Sound-color mappings have therefore been extensively investigated (Spence 2011; Hamilton-Fletcher et al. 2017). However, previous studies on color symbolism and perceptual studies mostly investigated focal colors and phonemes from a few languages rather than the underlying visual and acoustic parameters. Thus, we conducted two studies, looking for the perceptual dimensions that drive sound-color correspondences and for linguistic evidence of color sound symbolism.

In study I, we tested cross-modal correspondences between each visual (luminance, hue, saturation) and each acoustic (loudness, pitch, spectral centroid, F1, F2, trill) dimensions through Implicit Associations Task experiments. Around 20 participants with varying mother tongues were recruited online for each experiment which included 16 test blocks of 16 trials each. The participants were first taught a rule associating the left arrow button with one color and sound and the right arrow button with another color and sound. They were then presented with either color or sound stimuli and were asked to press the correct arrow key as quickly as possible. In following blocks, the rule changed. Colors were sampled from the perceptually accurate *CIE-Lab* space, and the sounds were created with a formant synthesizer in order to investigate correspondences between individual visual and acoustic dimensions. Measured accuracy and reaction time were analyzed using two Bayesian mixed models: a logistic model predicting accuracy and a log-normal model predicting reaction time in correct trials. The results showed that loudness and pitch were implicitly associated with luminance and saturation. While any upward shift of spectral energy was associated with higher luminance and saturation, changing formant frequencies of synthetic vowels failed to evoke any associations, as long as the spectral centroid remained constant. We also failed to discover robust associations between the hue of isoluminant colors and any acoustic characteristic. These findings suggest that sound-color mappings on a perceptual level concern relatively simple, quantitative dimensions of colors (luminance and saturation) and sounds (auditory frequency and loudness). If the same perceptual dimensions drive sound-color symbolism in world languages, we can expect to find associations based on quantitative visual and acoustic characteristics, rather than between specific focal colors and phonemes.

In study II, we investigated eleven color terms and related concepts (red-green, yellow-blue, black-white, gray, night-day, dark-light). The color name data was gathered from 245 areally spread language families and transcribed into The International Phonetic Alphabet (IPA). Each phoneme was described acoustically using high-quality IPA recordings (Lawson et al. 2015), and average color coordinates were extracted from languages of 110 non-industrialized societies (Regier et al. 2005). The acoustic parameters (sonority, brightness, spectral centroid, F_1, F_2 and F_3 for vowels and sonority and spectral centroid for consonants) were then correlated with the color words' visual parameters (luminance and saturation). As predicted from the results of Study I, vowels with high perceived brightness, sonority and F_1 were overrepresented in names of colors with high luminance. In addition, color saturation was associated with the sonority of consonants. Thus, our findings strongly indicate that quantitative dimensions (luminance, saturation, loudness, frequency) dominate over qualitative ones (hue, vowel quality) in color sound symbolism. The results are further corroborated by reports that synesthetes and non-synesthetes (Ward et al. 2006; Moos et al. 2014), toddlers (Mondloch & Maurer 2004) and chimpanzees (Ludwig et al. 2011) prefer to map high luminance to high pitch, and that infants (Adams 1987; Skelton et al. 2017) and macaques (Xiao et al. 2011) can distinguish between high and low saturation. Furthermore, the results also aligned strikingly well with the cross-linguistic order of how color words are lexicalized (Kay & Maffi 1999). These lexicalization patterns show that the most fundamental division of the color spectrum is between light and dark colors, followed by a division between warm and cool colors, i.e. the most and least saturated colors (Witzel & Franklin 2014). Hence, there seems to be a direct link between which parameters are used for mapping sound to color iconically and which parameters influence how colors are organized in the mental lexicon.

Thus, these findings help us understand how linguistic categories evolve and develop since semantic processing seems to be affected by fundamental cross-modal associations. These sound-color associations can furthermore be linked to the increased learnability provided by iconicity, as well as evolutionary, environmental, biological and developmental constraints.

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