



A Large-Scale Analysis of Music-Color Synesthesia

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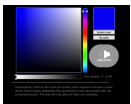
Introduction

Music-color synesthesia is a perceptual condition in which musical sounds trigger sensory experiences of color. We here employ data from 4,834 validated synesthetes who experience color in conjunction with instrument timbre, notes, and/or chords. Although synesthesia has been noted in the scientific literature for over a century, it is generally studied with small sample sizes. Here, with data from thousands of subjects, we address previous claims and discover new trends in music-color synesthesia, elucidate individual variability, and suggest structural form underlying chord-color assignments.

Quantifying Synesthesia

Testing for consistency

- An online questionnaire and battery of software tests freely available to the public, in many languages



www.synesthete.org

Instrument-color



Example subject, Score: 0.34
• 18 instrument sounds presented 3 times each (in random order)
• Inducers are recordings of "Twinkle, Twinkle Little Star"
• No visual representation of instrument shown

Note-color



Example subject, Score: 0.43
• 13 musical notes (on piano scale from middle C (271 Hz) to C one octave above (551 Hz)) presented 3 times each
• Quarter note on treble staff shown

Chord-color



Example subject, Score: 0.39
• 12 chords with root notes A, C, E, F# of major, minor, and diminished 7th qualities played on the piano 3 times each
• No visual representation of chord shown

Verification Process

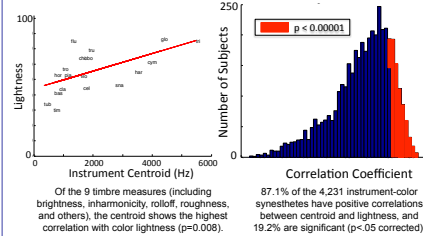
- Subject must assign colors to >50% stimuli
- Must have synesthesia (consistency) score of <1



Instrument-color Synesthesia

Does instrument timbre correlate with color?

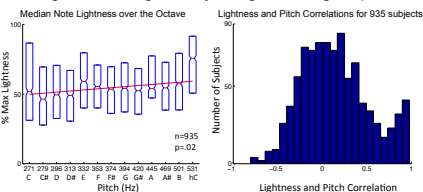
On average, yes. The centroid of each instrument's frequency spectrum correlates with the lightness of the color chosen.



Brightness and rolloff follow centroid as being most strongly correlated with lightness, suggesting that an instrument's average spectral frequency is the best indicator of color lightness.

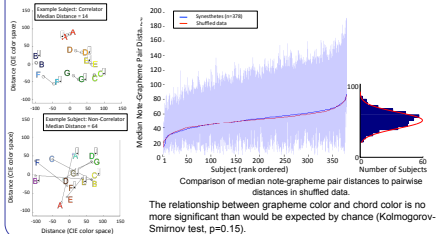
Note-color Synesthesia

Are lighter colors generally assigned to higher pitches?



Previous studies report that note-color synesthetes associate lighter colors with higher pitches (p=10, Ward et al. 2006). Results from a sample size of 935 subjects support this general trend, but individual analysis demonstrates that a small percentage of the population is largely responsible for overall correlation.

Are subjects with both grapheme and note-color synesthesia mapping letter colors onto note colors?

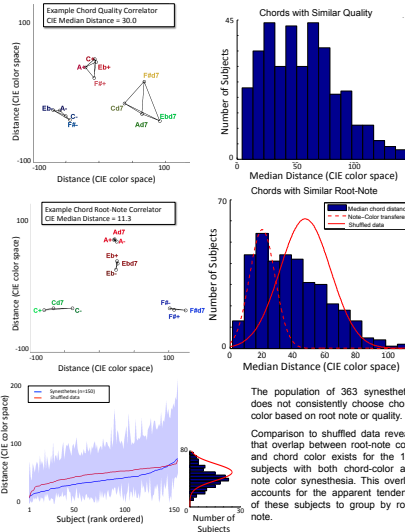


The relationship between grapheme color and chord color is no more significant than would be expected by chance (Kolmogorov-Smirnov test, p=0.15).

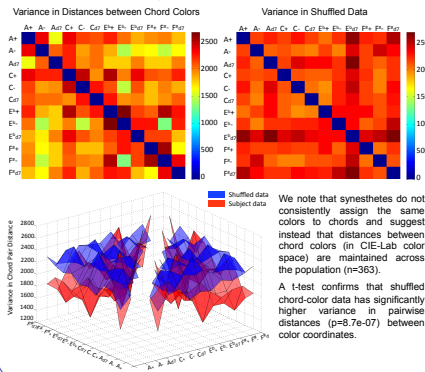
Chord-color Synesthesia

363 synesthetes experienced color for A, C, E^b, F# major, minor and diminished 7th chords. What is the relationship between chords and their associated colors?

1. Is color related to chord root-note or quality?



2. A relative measure for color assignments: the distance between the colors is significant, not the colors themselves

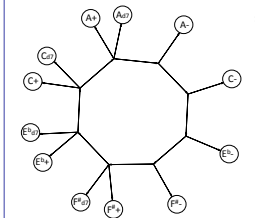


A Bayesian Model of Chord Color

What chord organization do consistent distances between colors maintain?

Multi-dimensional scaling suggests an architecture for color assignments.

We employ a Bayesian model to determine the structural form of highest probability given chord-distance data.



A ring structure of this form is the most probable chord organization given distances between colors. We note its similarity to the Circle of Fifths, an ordering of chords based on their number of sharps and flats.

We then calculated the amount by which each subject's ring differed from a Circle of Fifths structure, and repeated the process for shuffled color data. A Kolmogorov-Smirnov test confirms that the subject data is significantly more consistent with the Circle of Fifths (p=2.13e-33).

Synesthetes assign colors to chords in a manner such that the distances between chord-color preserves a structure resembling the Circle of Fifths.

Conclusions

- Average spectral frequency is the best indicator of instrument timbre-color lightness.
- Note-color synesthesia is distinct from grapheme-color synesthesia.
- While individual variability exists, note pitch and color are positively correlated.
- Grouping chords by root-note or quality does not reflect color assignments. Instead, synesthetes assign colors to chords in a manner that preserves distances between colors (regardless of the colors themselves) across the population.
- A Bayesian model suggests that consistent distances serve to organize chords into a ring structure similar to the Circle of Fifths.

References

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