Colors and Timbres

Consistency and Tendencies of Color-Timbre Mappings in non-synesthetic Individuals

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Background

A number of observations suggest that even non-synesthetic individuals show some consistent color-timbre mappings: Higher pitches are associated with brighter colors (Ward et al. 2006). Listeners match fast musical pieces mostly with yellow and red colors and slow pieces with green or blue colors (Palmer et al. 2013). Accordingly, faster attacks increase the selection of yellow (slower attacks the selection of blue) while higher spectral centroids increase the selection of red colors (Griscom 2014). Consonant intervals or chords are more frequently associated with green and blue colors than dissonant ones (Griscom 2014). Pictures with a great amount of yellow and with stony or metallic structures are more likely to be matched to screaming guitar sounds with a high inharmonicity and a strong MFCC4 (Mantscheff 2017). In literature, also a number of non-synesthetic cross-modal mappings between colors and musical instruments can be found:

	Hoffmann 1786, p. 57-58	Raff ca. 1855*	Fechner 1876, p. 215-216	Hoh 1878, p. 365	Lavignac 1895, p. 212-213	Mudge 1920, p. 343-344	Lange 1943, Spectrotone	Trofimova 1977	Ovsjanikov 2000
Flute low Flute middle Flute high	Carmine	dark blue blue light blue	blue	blue	blue (azure blue)	bright colors (24/50 persons) white	blue green yellow	light blue	silver light blue white
Oboe low Oboe middle Oboe high	roseate	yellow			green (sturdy green)		red orange yellow		
Clarinet low Clarinet middle Clarinet high	yellow				red (garnet red)	bright colors (19/50 persons)	blue green yellow	green	blue brown violet
Bassoon low Bassoon middle Bassoon high	violet	black to grey			brown (mixed with grey)		green green green		
French Horn low French Horn middle French Horn hoch	purple (Ultramarine with crimson)	green			yellow (copper yellow)		violet brown red		
Trumpet low Trumpet middle Trumpet high	red (cinnabar)	red (scarlet)	red	red	red (purple red)		brown red yellow	red orange yellow purple	red orange yellow
Trombone low Trombone middle Trombone high		violet (purpur)		red	red (purple red)	yellow (14/50 persons) brown	brown red orange		
Tuba low Tuba middle Tuba high							violet violet black		
Violin low Violin middle Violin high	light blue				all colors	blue (35/50 persons) violet	violet blue green yellow white	light blue	yellow bright silver
Cello low Cello middle Cello high	dark blue	*cited in Bleuler & Lehmann, p. 64			all colors	brown (19/50 persons) red	violet green green blue yellow white	blue violet black brown	brown violet blue

Fig. 1: Color-Instrument-Mappings by non-synesthetic persons and authors from the 18th to 20th century

Aims

- **Can consistent matchings of colors and timbres of musical instruments be found in non-synesthetic individuals?**
- **Are they similar to previously described color-timbre mappings?**
- **Are there correlations between color associations and specific timbre features?**

Methods

Similarly to the music-color-test done by Palmer et al. (2013) and Griscom (2014), the color stimuli used here consist of the 38 Berkeley Color Project colors (BCP). They are displayed simultaneously in the form of 100x100 pixel colored squares against a neutral gray background. While viewing this color matrix, 40 subjects listened to 10 orchestral instrument sounds taken from the Vienna Symphonic Library (flute, oboe, clarinet, bassoon, French horn, trumpet, trombone, tuba, violin, cello) played at three different pitches each (high, middle, low register) and in two types of articulation (staccato, legato). For each sound, listeners were asked to choose three colors that match best with the instruments' timbre. Furthermore, for all stimuli, a collection of timbre features was extracted using signal analysis techniques (Lartillot & Toiviainen 2007; Genesis 2009; Driedger & Müller 2015) and the color choices were tested for correlations with the examined timbre features.

Fig. 2: Berkeley Color Project palette (BCP; Palmer et al. 2013)

Results

Almost no differences could be found for the distribution of color choices depending on articulation (legato vs. staccato sounds).

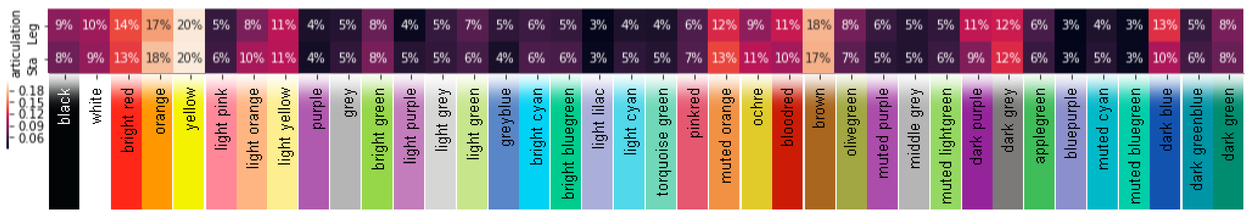

Fig. 3: Heatmap comparing the relative frequency of color choices for legato (Leg) and staccato (Sta) sounds in comparison

Results

As a whole, color choices seem to be more pitch dependent than timbre dependent: The most popular choices comprised a spectrum of mostly brown, orange and yellow colors (brown for low pitches, yellow for high pitches), as well as sometimes blue/grey/black colors for the low register of nearly all instruments (except oboe and violin).

timbre / octave	E2	E3	E4	E5	E6
Flute			light orange	light yellow	yellow
Oboe			muted orange	orange	yellow
Violin			muted orange	yellow	yellow
Clarinet		dark purple	brown		yellow
Trumpet		brown	yellow	yellow	
Trombone	brown	brown	yellow		
French Horn	brown	orange	yellow		
Bassoon	brown	brown	light orange		
Cello	brown	brown	orange		
Tuba	brown	brown	brown		

Fig. 4: most frequent color choices when grouped by instrument and octave

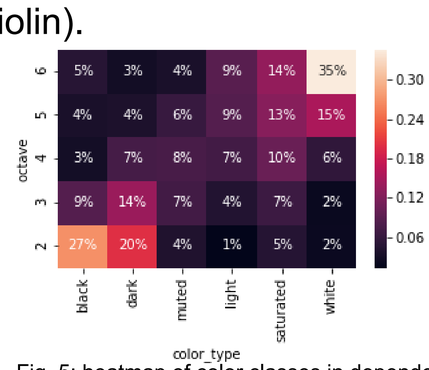

Fig. 5: heatmap of color classes in dependency of the pitch (octave)

Generally, high pitched stimuli were more often matched with white and light colors (consistent with Ward et al. 2006), as well as more saturated colors, while stimuli from the lower octaves tended to be paired with black or dark colors (see Fig. 5).

The overall agreement between individual raters concerning specific color choices was low (Fleiss' Kappa = 0.0706; Intraclass Correlation Coefficient (two-way model, agreement) of the ratings = 0.0671).

When analysing the distribution of color choices across different instruments via Fisher's exact tests, certain characteristic accumulations can be observed (see Fig. 6). E.g. the trumpet was often associated with red and yellow colors, which corresponds very well to previously described instrument-color-mappings in literature. Certain instruments like flute, oboe, clarinet, trumpet and violin are often associated with white and light colors, especially when being played in high pitches.

Flute	Oboe	Violin	Clarinet	Trumpet	Trombone	Fr. Horn	Bassoon	Cello	Tuba
0,0000	0,0000	0,0000	0,0001	0,0000	0,0006	0,0003	0,0001	0,0000	0,0000
0,0000	0,0000	0,0000		0,0000	0,0019	0,0012	0,0016	0,0004	0,0000
0,0000	0,0002	0,0006		0,0012	0,0082	0,0094	0,0022	0,0013	0,0000
0,0001	0,0098	0,0081					0,0074	0,0064	0,0006
0,0001		0,0088							0,0020
0,0003									0,0032
0,0009									0,0088
0,0022									
0,0055									

Fig. 6: Colors that were significantly more often chosen for samples of the specified instruments (according to Fisher's exact test of each instrument-color-combination compared to the remaining instruments and colors (p <= 0.01 included))

In an analysis of the timbral attributes of the stimuli signals, it can be seen that there is a positive correlation between the brightness of the selected mean color and features that are related to the fundamental frequency and (timbral) brightness like the spectral centroid, the spectral energy between 2 and 4 kHz, spectral roll-off, and certain MFCCs. Including the RGB channels did not add any more information as they were strongly correlated with the grey value / brightness.

	R_weighted	p	G_weighted	p	Hue_weighted	p	Bright_weighted	p	greyvalue	p
brightness2	0,721	0,000	0,584	0,000	-0,498	0,000	0,666	0,000	-0,675	0,000
khz2to4Energy	0,697	0,000	0,570	0,000	-0,525	0,000	0,620	0,000	-0,665	0,000
loudnessSone	0,444	0,000	0,455	0,000	-0,069	**0,602**	0,465	0,000	-0,470	0,000
mfcc1	-0,822	0,000	-0,758	0,000	0,421	0,001	-0,819	0,000	0,823	0,000
mfcc3	-0,533	0,000	-0,534	0,000	0,483	0,000	-0,542	0,000	0,585	0,000
mfcc7	-0,592	0,000	-0,615	0,000	0,605	0,000	-0,579	0,000	0,660	0,000
mfcc8	-0,390	0,002	-0,454	0,000	0,518	0,000	-0,387	0,003	0,478	0,000
mfcc9	0,536	0,000	0,482	0,000	-0,508	0,000	0,445	0,000	-0,544	0,000
mfcc10	0,472	0,000	0,428	0,001	-0,456	0,000	0,443	0,000	-0,494	0,000
mfcc13	-0,535	0,000	-0,514	0,000	0,646	0,000	-0,468	0,000	0,579	0,000
percussiveEnergy	-0,640	0,000	-0,712	0,000	0,066	**0,620**	-0,729	0,000	0,691	0,000
roughness	-0,640	0,000	-0,718	0,000	0,019	**0,888**	-0,734	0,000	0,687	0,000
spectralCentroid	0,749	0,000	0,646	0,000	-0,535	0,000	0,684	0,000	-0,727	0,000
spectralFluxMean	0,464	0,000	0,456	0,000	-0,241	**0,066**	0,434	0,001	-0,481	0,000
spectralRolloff	0,670	0,000	0,532	0,000	-0,488	0,000	0,596	0,000	-0,620	0,000
tonalEnergy	0,416	0,001	0,469	0,000	-0,051	**0,702**	0,485	0,000	-0,456	0,000

Fig. 7: Correlation matrix of timbre features and color values

Conclusion

With an overall relatively low agreement between individual raters, timbre-color associations turned out to be most robust in regard to pitch / timbral brightness: low pitches are more often associated with dark colors (especially brown) while stimuli with high pitch and timbral brightness are more often associated with lighter and more saturated colors (especially orange or yellow). Concerning instrumental timbre some parallels to previous findings can be observed, such as the association between trumpet and red, flute in low register and blue, or flute/clarinet/violin in high register and yellow/white (Hoffmann 1786, p. 57-58; Fechner 1876, p. 215-216; Hoh 1878, p. 365; Lange 1943; Trofimova 1977; Ovsjanikov 2000, p. 109 and 111).

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