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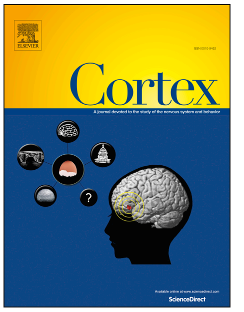

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Timbre-colour synaesthesia: Exploring the consistency of associations based on timbre.

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Synaesthesia is a rare developmental condition, in which one property of a stimulus evokes an additional percept, e.g. in music-colour synaesthesia musical sounds elicit experiences of colour (Simner et al., 2006). Synaesthetic associations are very specific and consistent over time (Ward, 2013). Indeed, consistency is often considered to be the best method for testing the authenticity of synaesthesia (Simner, 2012).

Music-colour synaesthesia seems to be a frequent variant of the wider condition (Day, 2005); however, prior research has focused on associations based mostly on pitch; other auditory attributes (e.g. timbre) have been relatively unexplored. Our aim was to identify timbre-colour synaesthetes and measure the consistency of their associations. Although a test for consistency of timbre-colour associations exists in the Synesthesia Battery (Eagleman et al., 2007), the stimuli used are short melodies providing not only timbral but also pitch and musical interval information. For this reason a new online test was constructed to explore the associations based only on timbre. Synaesthetes were expected to show higher consistency of colour selection compared to controls.

Synaesthetes were screened using Eagleman et al.'s (2007) musical-instrument colour test. Three females (AW, PE, RC) aged 59, 58 and 41 years old respectively (M = 52.67, SD = 10.12) who scored within the synaesthetic range participated in our experiment. Each synaesthete was matched to a control group of the same gender and age; AW and PE were matched to the same control group (n=7, M = 57.43, SD = 2.87) due to their similarity in age, while RC was matched to a second control group (n=5, M = 39.4, SD = 2.33).

The new online test (http://psy770.gold.ac.uk/scsyn) comprised two sections; the first was a short questionnaire regarding demographics and the nature of synaesthetic experiences; the second was an internal consistency task similar to Eagleman et al.'s (2007) musical instrument-colour test. The stimuli were real sounds of all musical instrument families taken from the McGill University Master Samples (MUMS, 1987) and edited on Audacity® to be one-second long. Stimuli were matched for perceived loudness and pitch (as per Marin, Gingras & Stewart, 2011).

Fourteen instrument tones, each pitched at C4, comprised the stimulus set. For 5 out of these 14 instruments, G4 tones were also included as foils to reduce the use of strategic memorising that could artificially inflate the consistency scores, but these were excluded from the analysis. All sounds were played three times in random order totaling 57 trials.

For colour selection, a colour picker comprising a slider for choosing colour category and a second slider for more fine-grained colour specification was used. Participants could see their selection in a solid rectangle below the colour picker as well a “Replay Sound”, a “Submit Colour” and a “No Colour” button. Participants were instructed to assign a colour to each stimulus without using any external aids. They could replay the sounds and modify the colours until they submitted the colour. Participants could not go back to a previous trial. The colour picker reset to a random location in the colour space for each new trial.

Consistency of colour selection was measured using Eagleman et al.’s (2007) formula for calculating the colour distance across trials in RGB space. Lower scores reflect higher consistency. Consistency was also calculated using the same formula by converting RGB values into CIELUV colour space, as this measure has been shown to have greater sensitivity and specificity relative to RGB space consistency (Rothen, Seth, Witzel & Ward, 2013).[Two-panel figure]

Each synaesthete’s performance on the task was compared to controls using Crawford and Garthwaite’s modified t-test (Crawford & Garthwaite, 2002). Since synaesthetes were expected to be more consistent, a one-tailed test was employed. Using the RGB consistency scores, two of the three synaesthetes were significantly more consistent than the controls: PE (Score = 1.23) compared to controls (M = 2.61, SE = .25), $t(6) = -1.96$, $p<.05$, zCC = 2.09 and RC (Score = 1.17) compared to controls (M = 2.42, SE = .13), $t(4) = -3.94$, $p<.05$, zCC = 4.31, where zCC denotes the effect size of the comparison (see Crawford, Garthwaite & Porter, 2010). The third synaesthete was more consistent than controls, but not significantly so: AW (Score = 1.63) compared to controls (M = 2.61, SE = .25), $t(6) = -1.39$, *ns*, zCC = 1.49.

Using CIELUV scores, all synaesthetes were significantly more consistent than controls: PE (Score = 131.96) compared to controls (M = 393.57, SE = 44.43), $t(6) = 370.78$, $p<.001$, zCC = 396.38; AW (Score = 210.52) compared to controls (M = 393.57, SE = 44.43), $t(6) = -259.44$, $p<.001$, zCC = 277.35 and RC (Score = 194.77) compared to controls (M = 334.52, SE = 21.29), $t(4) = -2.68$, $p = .028$, zCC = 2.94.

Thus, our experimental hypothesis is supported. The difference between RGB and CIELUV consistency for AW is likely to be due to consistency measures based on perceptual CIELUV colour models providing greater sensitivity and specificity than RGB consistency (Rothen et al., 2013).

In summary, it can be argued that a variant of synaesthesia where the timbre of an instrument evokes an atypical perception of colour does exist and such associations seem to be consistent over time. Future studies can be designed to shed light on the level of processing at which the synaesthetic associations occur e.g. whether the visual experiences elicited are related to semantic or purely acoustic properties of the instruments. Further, it will be necessary to devise more sophisticated approaches to measure consistency when synaesthetic experiences are complex (for example, a synaesthete described her elicited percepts as a set of colors with a common quality, e.g. metallic colour set, dark colour set, which she could not represent on the colour picker and as such was not tested), as is often the case in cases of timbre-colour synaesthesia.

Acknowledgments

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Instrument	Trial 1	Trial 2	Trial 3	Instrument	Trial 1	Trial 2	Trial 3
C4 Accordion				C4 Tuba			
C4 Acoustic guitar				C4 Tubular Belles			
C4 Bassoon				C4 Vibraphone			
C4 Flute alto				C4 Violin			
C4 French horn				G4 Lute			
C4 Lute				G4 Marimba (soft mallet)			
C4 Marimba (soft mallet)				G4 Piano (MPP loud)			
C4 Piano (MPP loud)				G4 Saxophone			
C4 Saxophone				G4 Tuba			
C4 Trombone (tenor)							

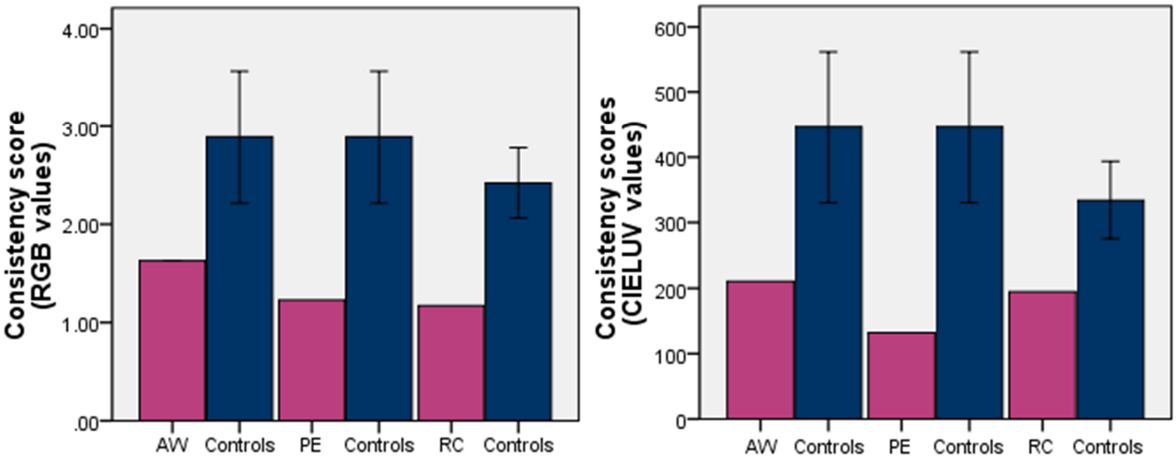

Figure 1. Top panel: RC's colour selections for all stimuli. Lower panel: Consistency scores of synaesthetes and corresponding controls measured in RGB and CIELUV values (Error bars: 95% Confidence Interval).