Neural correlates of colour category processing

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1- Introduction

The category difference in colour perception has behavioural consequencies: stimuli crossing a colour boundary (between-category) are easier to distinguish than otherwise equidistant stimuli drawn from within the same category [1]. Goldstone [2] proposed that these categorical effects could be explained by an expansion of the perceptual continuum at the categorical boundary and/or a compression of the continuum within each category (see also [3]).

Colour category differences have been argued to be innate [1] or, alternatively, to derive from terms in the speaker's language [4]. Recent support for the latter hypothesis would appear to come from Gilbert, et *al.* [5] who found a left hemisphere advantage for between-category colour discrimination suggesting a role of language brain areas in colour category processing. However, their results could not distinguish between effects due to changes to early level visual cortex and explanations that rely on post-perceptual mechanisms [6]. In order to resolve this problem, we used a neuroimaging technique that reveals high temporal resolution such as event-related potential (ERP).

2 - The present study

We aim to investigate neuronal correlates of colour difference by comparing a between-category (Blue vs. Green Go) and within-category (Green Go *vs.* Green G1) processing. Those two conditions compared contrasts of equal physical magnitude. Thus, the present study defined the temporal dynamics of neural correlates for colour categories by characterizing precisely their differences from simple colour differences that we know emerge during early sensory processes.

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3 - Method

Stimuli

- Squares of four colours (visual angle: 25° x 25°, viewing distance: 100 cm) derived from Munsell colours (lightness V=6 and saturation C=10 constant) Green (2.5BG = Go), Blue (4.8B = B), Green (0G = G1), and Red (5R = R)
- 6 different blocks. For each (400 stimuli) = 280 standard colours, 60 deviant colours and 60 cartoon pictures (standard/deviant/picture: 0.70/0.15/0.15)
- Stimulus presentation = 200 ms; Interstimulus interval (ISI) randomized from 600 to 950 ms

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Standard	Go	R	Go	B	Go	G1
Deviant	R	Go	B	Go	G1	Go
	Large Deviance Between Category		*Small Deviance Between Category*		*Small Deviance Within Category*	

Participants

- Twenty right-handed native English participants (7 males, 18-29 years old, mean = 20 years)

Procedure

- Presentation order of blocks balanced across participants
- Detection of infrequent cartoon characters embedded within blocks of sequentially presented colour patches
- Behavioural task: press a button with their right hand "as quickly as possible" whenever the target (pictures) was presented

EEG recording

- Biosemi system with 64 electrodes, 512 Hz sampling rate and bandpass (0.1-100 Hz)
- ERPs re-averaged offline with the average reference
- ERPs analyzed from the Go colour for each stimulus type (Standard, Deviant) presented in different contexts (R, B, G) for each participant

ERP analysis

- Three dependent variables were measured: mean amplitudes (mean average amplitude within a time window of interest in πV), peak amplitudes (highest or lowest peak in πV), peak latencies (highest or lowest peak latency on the curve in ms)
  - Mean amplitudes for selected electrodes grouped in Regions Of Interest
    - P100: 120-160 ms
    - N100: 160-200 ms
    - P200: 200-240 ms
    - N200: 240-280ms
  - Peak amplitudes and peak latencies for four selected electrodes Afz, Fz, Oz, Iz on the difference wave (Deviant minus Standard) in the time window 120-280 ms
- Raw & Normalized data, Greenhouse-Geisser correction

References

[1] Bornstein, M.H. & Korda, N.O. (1984) Psychological Research, 46, 207-222.
[2] Goldstone, R. (1994) Journal of Experimental Psychology: General, 123, 178-200.
[3] Harnad, S. (1987) Categorical perception: The groundwork of cognition. Cambridge University Press, Cambridge.
[4] Davidoff, J., Davies, I.R.L. & Roberson, D. (1999) Nature, 398, 203-204.
[5] Gilbert, A.L., Regier, T., Kay, P. & Ivry, R.B. (2006) Proc Natl Acad Sci U S A, 103, 489-494.
[6] Pilling, M., Wiggett, A., Ozgen, E. & Davies, I.R.L. (2003) Memory and Cognition, 31, 538-551.
[7] Kimura, M., Katayama, J. & Murohashi, H. (2006) Psychophysiology, 43, 180-189.
[8] Schendan, H.E., Ganis, G. & Kutas, M. (1998) Psychophysiology, 35, 240-251.

4 - Results

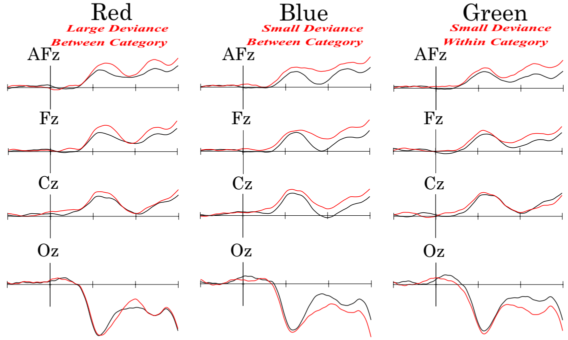

Fig 1: Grand mean average ERPs for a subset of 4 electrodes (AFz, Fz, Cz, Oz) for the standard and deviant stimuli for each colour. In this figure, negativity is plotted up and ERPs have been filtered at 10 Hz for the display. In all 3 condition (R, B, G) the deviant simtuli elicited more negativity in frontal sites and more posititivty in the posterior electrodes compared to the standard stimuli. This effect correspond to the "change-related positivity" [7] and has been recorded between 120 and 160 ms for the Red context, between 160 and 200 ms for the Blue context and between 160 to 280 ms for the Green context.

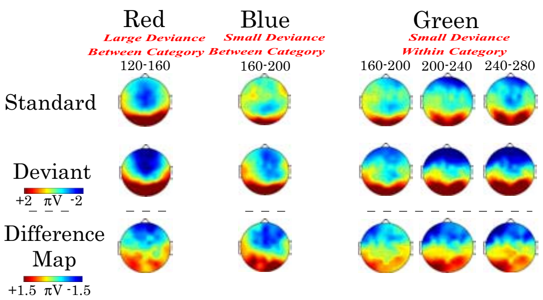

Fig 2: Isovoltage maps of standard and deviant for each colour within time windows showing significant topographical differences. The difference maps (deviant minus standard) show the distribution of the change-related positivity at posterior electrodes for each colour. No topographical differences were recorded between the different colour contexts.

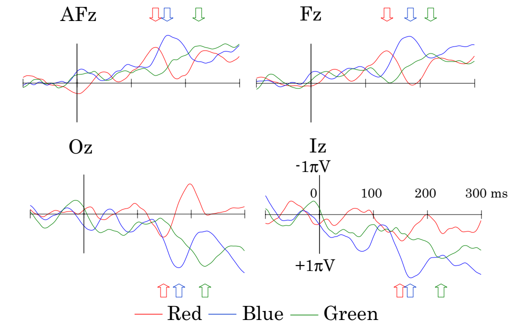

Fig 3: Difference waves (Deviant minus Standard) in each colour condition at four selected electrodes (Anterior: AFz, FZ and Posterior: Oz and IZ). Arrows indicate the modulation of the change-related positivity with the colour. Results revealed a significant effect of context colour on the latency but not on the amplitude of the change-related positivity.

5 - Discussion & Conclusion

- We compared ERPs elicited by physically identical stimuli (Go) in three different contexts and showed clear differences related to both the magnitude and categorical status of colour deviancies: the change-related positivity.
- Magnitude effect: The red context showed an earlier (161 ms) change-related positivity compared to the blue context (195 ms).
- Categorical effect: The between-category (Blue context) showed an earlier (195 ms) change-related positivity compared to the within-category (Green context, 214 ms) condition.
- Categorization as simple as colour appears to operate with the same temporal dynamics as other apparently more complex visual categorization tasks [8].
- No laterality effects emerged in the contrast between colours not even for those categorically different (red *vs.* green, and blue *vs.* green). Our data thus do not provide evidence for an early level locus for the recent behavioural findings of a left hemisphere superiority for colour categories [5].

In conclusion, we have demonstrated that both colour difference and colour categorical information are used during passive discrimination of visual events. Colour categorisation takes place rapidly and was observed as early as 160 ms following stimulus onset. Indeed, colour categorisation appears to take priority within visual analysis because the latency of an ERP correlate was reduced compared to that of an otherwise equal colour discrimination.