ASSOCIATING COLOURS WITH PEOPLE: A CASE OF CHROMATIC-LEXICAL SYNAESTHESIA

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INTRODUCTION

Synaesthesia is a condition in which a sensory experience normally associated with one modality occurs when another modality is stimulated (Baron-Cohen and Harrison 1997). The commonest form of synaesthesia is colour-word synaesthesia, which is subdivided into a chromatic-graphemic type (the dominant letter in a word induces a letter-specific colour experience) and a chromatic-lexical type (each word triggers a specific colour experience) (Baron-Cohen and Harrison 1997). To date, little is known about the neural mechanisms associated with synaesthesia (Grossenbacher and Lovelace 2001, Paulesu et al., 1995).

Here, we report the case of R.S. with chromatic-lexical synaesthesia for names of personally familiar people. To the best of our knowledge, this is the first report of such a form of synaesthesia. Functional imaging (fMRI) was used to elucidate the neural basis of this form of chromatic-lexical synaesthesia and the interaction of synaesthetic colour experience with the non-synaesthetic perception of external colour.

METHODS

R.S., a 20 year-old, right-handed female student, with an IQ of 118 and without neurological or psychiatric illness, underwent neuropsychological testing to exclude dysfunction of the visual system. She scored above average in the Benton Line Orientation Test, Hooper Visual Organization Test, and the Visual Space and Object Perception Testbattery (VOSP). She also performed well on tests of colour vision, neglect and constructive abilities. The genuineness of R.S.'s synaesthesia was tested by recording her colour experiences on two separate occasions without prior warning (re-test interval of 12 months) (Baron-Cohen et al., 1993): R.S.'s responses were consistent for 107 of the 116 tested items (92.2%). R.S. associated the non-coloured test-items with 11 different colours (blue, brown, black, gold, green, grey, pink, red, yellow, violet, white), five of which were further subdivided by different shades. The pattern of her synaesthetic colour experience, which did not depend on either the letter-graphemes or the phonemes of the test items, classified her as a chromatic-lexical synaesthete (Baron-Cohen et al., 1993).

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Individual sets of personally familiar names, which induced synaesthesia (Syn+), and of unfamiliar names, which did not induce synaesthesia (Syn-), were created. These stimuli were visually presented to R.S. in either a pseudo-randomly assigned colour (Col+) or in grey (Col-). The colour of a stimulus never matched the associated synaesthetically experienced colour. This constitutes a factorial design with the factors Synaesthesia (Syn+/-) and Colour (Col +/-). During scanning, blocks of 12 names were used (stimulus onset time 1800 ms, inter-stimulus interval 200 ms) with each block being alternated with a rest period. R.S. indicated via button press whether or not an item induced synaesthesia. Responses and reaction times (RT) were recorded with an optic fibre tapping apparatus. Functional MR images were acquired on a Siemens Vision® 1.5T scanner using standard EPI imaging procedures and statistical analysis (see Fink et al., 2000). The significance level was set at $p = 0.001$, uncorrected, for height, with an extent threshold of $p = 0.05$.

Results

Colour activated the fusiform gyrus bilaterally. In stereotactic space (Talairach and Tournoux 1988), these activations were located at $x = +36$, $y = -80$, $z = -20$ and $x = -34$, $y = -70$, $z = -20$ with a Z-score of 3.8 and 4.5, respectively. These areas correspond to V4 (Zeki et al., 1991). Synaesthesia for personally familiar names activated retro-splenial cortex ($x = -2$, $y = -56$, $z = +30$; $Z = 3.9$; [2] in Figure 1) and extra-striate cortex bilaterally (left: $x = -48$, $y = -74$, $z = +4$; $Z = 3.0$; right: $x = +52$, $y = -70$, $z = -10$; $Z = 4.0$; [1] and [3] in Figure 1). The extra effect of synaesthetically experienced colour in the presence of a coloured stimulus [interaction term: (Syn+/Col+ > Syn+/Col-) > (Syn-/Col+ > Syn-/Col-)] activated right prefrontal cortex only ($x = +48$, $y = +56$, $z = -8$; $Z = 4.0$).

Interestingly, there was a corresponding significant interaction [$F(1,32) = 6.0$, $p < 0.05$] of RT for synaesthesia-inducing stimuli with longer RT for coloured (710 ms ± 36 ms) versus non-coloured (594 ms ± 36 ms) stimuli. Throughout the imaging study R.S. showed consistent responses with synaesthesia present for all synaesthesia inducing stimuli (100% synaesthesia in Syn+/Col+ and Syn+/Col-) and synaesthesia absent for the control stimuli (0% synaesthesia in Syn-/Col+ and Syn-/Col-).

Discussion

In this functional imaging study of a special case of chromatic-lexical synaesthesia (R.S.), we employed a factorial design which allowed us to separately examine the neural basis of R.S.'s colour perception, the neural mechanisms associated with her experience of chromatic-lexical synaesthesia for names of personally familiar people, and the interaction thereof. The latter is of particular interest as it reveals the extra effect of colour in the presence of synaesthesia, which we hypothesized to isolate the neural mechanisms underlying the conflict caused by competing external and synaesthetic colour experience.

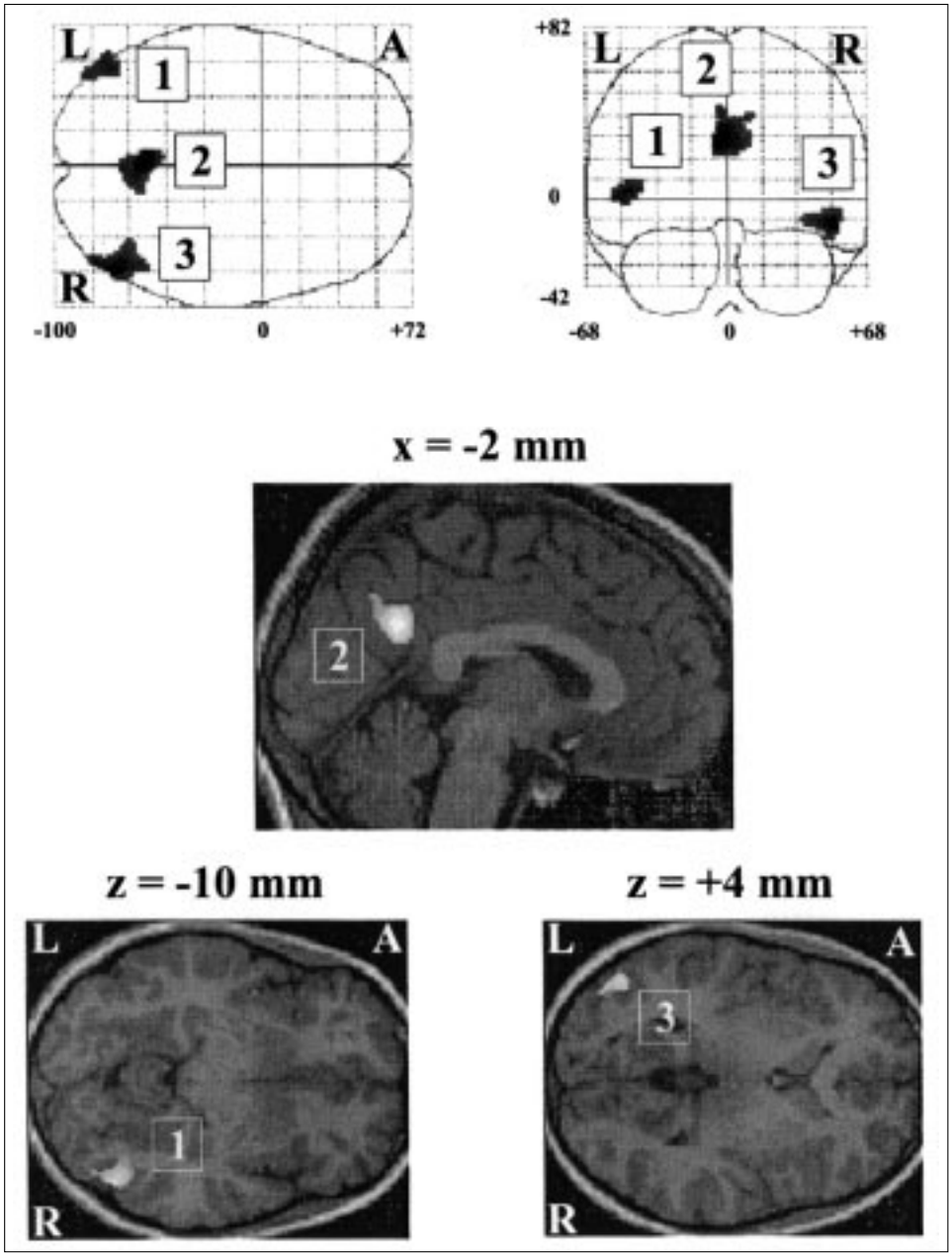

Fig. 1 – *Relative increases of neural activity (measured by changes in BOLD signal) associated with R.S.'s experience of synaesthesia for personally-familiar names. In the upper part of the figure, areas of significant relative increase in neural activity (p = 0.001, uncorrected for multiple comparisons) are shown as through-projections onto representations of standard stereotactic space (Talairach and Tournoux 1988). The exact coordinates of the local maxima within the areas of activation (1: left extra-striate cortex, 2: retro-splenial cortex, 3: right extra-striate cortex) and their Z statistics are given in the text. The numbers on the axes refer to coordinates of standard stereotactic space (Talairach and Tournoux 1988). In the lower part of the figure, the activated areas are displayed superimposed on a sagittal and two transverse MR sections of R.S.'s brain after co-registration and superimposition of R.S.'s structural MR and functional MR images. Coordinates above the sections indicate the level of sectioning.*

R = right, L = left, A = anterior. Syn+ = synaesthesia present, Syn = synaesthesia absent; Col+ = colourful stimuli, Col- = grey stimuli.

Perception of external colour in R. S. activated V4 bilaterally. This indicates that the neural basis of colour perception in R.S. is not different from that of non-synaesthetes. R.S.'s experience of synaesthetic colour for personally familiar names seems to be mediated by an interaction of retro-splenial cortex, a region previously associated with person familiarity (Shah et al., 2001) and emotional salience (Maddock, 1999), with secondary (extra-striate) visual areas. Thus in R.S., the neural mechanisms underlying her particular form of synaesthesia differ from those associated with colour perception. This implies that synaesthesia goes beyond being a simple 'disorder' of the colour perception system. In this context, it is important to remember that we controlled for the effect of external colour in our factorial design since both synaesthesia-inducing and non-synaesthesia inducing items were shown in colour.

The interference between externally presented and internally synaesthetically-experienced colour, which was behaviourally reflected by a significantly prolonged RT for coloured, synaesthesia-inducing stimuli, yielded an additional activation in right prefrontal cortex. This area has previously been implicated in monitoring sensory conflicts (Fink et al., 1999). Taken together, both the behavioural and the functional imaging data thus suggest that the interference of external colour with synaesthetic colour leads to an increased internal monitoring demand to control the externally triggered but internally generated conflict of the senses.

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