

available at www.sciencedirect.comjournal homepage: www.elsevier.com/locate/cortex

Research report

The neural correlate of colour distances revealed with competing synaesthetic and real colours

Bruno Laeng^{a,b,*}, Kenneth Hugdahl^{b,c} and Karsten Specht^{b,d}

^a Department of Psychology, University of Oslo, Norway

^b Department of Biological and Medical Psychology, University of Bergen, Norway

^c Division of Psychiatry, Haukeland University Hospital, Bergen, Norway

^d Department of Clinical Engineering, Haukeland University Hospital, Bergen, Norway

ARTICLE INFO

Article history:

Received 19 December 2008

Reviewed 7 May 2009

Revised 8 July 2009

Accepted 31 August 2009

Action editor Jason Mattingley

Published online 17 September 2009

Keywords:

Synaesthesia

Colour vision

Neuroimaging

fMRI

Stroop

ABSTRACT

Synaesthetes claim to perceive illusory colours when reading alphanumeric symbols so that two colours are said to be bound to the same letter or digit (i.e., the colour of the ink, e.g., black, and an additional, synaesthetic, colour). To explore the neural correlates of this phenomenon, we used a Stroop single-letter colour-naming task and found that distances in colour space between the illusory and real colours of a letter target (as computed from either the RGB or CIExY coordinates of colours) systematically influenced the degree of neuronal activation in colour-processing brain regions. The synaesthetes also activated the same fronto-parietal network during the classic colour-word Stroop task and single-letter tasks. We conclude that the same neural substrate that supports the conscious experience of colour, as triggered by physical wavelength, supports the experience of synaesthetic colours. Thus, two colour attributes (one that is wavelength-dependent and one that is illusory) can be bound to the same stimulus position and simultaneously engage the colour areas in proportion to their similarity in colour space.

© 2009 Elsevier Srl. All rights reserved.

A minority of people in the normal population report a phenomenon, called synaesthesia, which seems to entirely escape the possibility of “knowing what it is like” either through shared physical stimulation or by reference to past experience. Most synaesthetes (Rich et al., 2005; Simner et al., 2005) report the intrusion of colour sensations that are systematically triggered by stimuli that are not coloured per se (e.g., black-printed alphanumeric symbols). This has been labeled grapheme-colour synaesthesia. Specifically, a synaesthete may report seeing the letter A as generating the sensation of two colours, one being that of the ink (or pixels), which depends on physical wavelengths, and the other being an

illusory colour that only the synaesthete experiences. Differently from the illusory experiences of colour afterimages, which can be easily verified by any normal observer, synaesthetic experience is absolutely subjective and highly idiosyncratic. In fact, synaesthetes’ reports appear “alien” or illogical to the majority of (non-synaesthetic) individuals (e.g., “how can a letter have two colours simultaneously?”). In contrast, dreams or pain states, although private and idiosyncratic, can be framed in terms of everyone’s common experience. Nevertheless, despite its elusiveness, recent research on synaesthesia has proved it to be a genuine phenomenon (e.g., Hubbard and Ramachandran, 2005; Robertson and Sagiv, 2005).

* Corresponding author. Department of Psychology, University of Oslo, 1094 Blindern, 0317 Oslo, Norway.

E-mail address: bruno.laeng@psykologi.uio.no (B. Laeng).

0010-9452/\$ – see front matter © 2009 Elsevier Srl. All rights reserved.

doi:10.1016/j.cortex.2009.09.004

Current research has revealed that synaesthetic ‘photisms’ can either assist or interfere with performance in visual tasks (Hubbard et al., 2005) and real and synaesthetic colours are able to interact perceptually (Kim et al., 2006). Interference effects arise when naming the “objective” colour of an object (e.g., a letter A) when at the same time this evokes a “subjective” or synaesthetic colour (Wollen and Ruggiero, 1983; Dixon et al., 2000; Mattingley et al., 2001; Nikolich et al., 2007). That is, when the “objective” and “subjective” colours are incongruent (e.g., the letter B is printed in red but evokes also the colour green) there is interference compared to when the colours are congruent (e.g., the B is in green). Most remarkably, synaesthetes can identify and localize a target object (e.g., one digit 5) among distracting objects (e.g., several digits 2) more efficiently than non-synaesthetes, if the target and distractors differ by a synaesthetic colour feature (e.g., Palmeri et al., 2002; Laeng et al., 2004; Laeng, 2009). For some of these subjects and in some situations, the synaesthetic colours can “pop out” or, more precisely, cause an accelerated narrowing of attention onto a purely synaesthetically defined odd-man-out element of a scene.

Neuroimaging seems a particularly appropriate tool for revealing whether a sensory experience is actually occurring when there are no ways for other observers to obtain the same experience and verify it. Studies in neuroscience indicate that colour is represented in a network of cortical areas of the human brain, located medially and inferior in the occipital and temporal lobes (Gulyas et al., 1994; Hadjikhani et al., 1998; McKeefry and Zeki, 1997a, 1997b; Tootell and Hadjikhani, 2001; Wade et al., 2002; Zeki and Moutoussis, 1997). Cortical areas responsive to colour include portions of the lingual and fusiform gyrus (Bartels and Zeki, 2000; Corbetta et al., 1991; Lueck et al., 1989). Most interestingly, the colour-processing areas V4 and V8 are active in normal individuals when they experience ‘illusory’ colours in the absence of chromatic stimuli, e.g., when seeing colour afterimages (Barnes et al., 1999; Hadjikhani et al., 1998; Morita et al., 2004; Sakai et al., 1995). Remarkably, it has been reported that these same areas can also be active when synaesthetes report experiencing their illusory colours (e.g., Nunn et al., 2002; Hubbard et al., 2005; Rich et al., 2006; Sperling et al., 2006; Steven et al., 2006).

The goal of the present study was to investigate what is perhaps the most puzzling phenomenon regarding the synaesthetic reports of some grapheme-colour synaesthetes who can apparently “project” the illusory colour in their visual field (e.g., Dixon et al., 2004; Rouw and Scholte, 2007): That is, a single visual stimulus (i.e., the shape of an alphanumeric symbol) is perceived as having two colours at the same time.

In neural terms, ensembles of colour-opponent neurons in the colour-processing areas V4 and V8 (Hadjikhani et al., 1998; Tootell and Hadjikhani, 2001) might simultaneously code (for unknown reasons) both colours in the synaesthete’s brain, so that two colour attributes can be bound to the same stimulus and, for some synaesthetes (as the ones investigated in the present study), to the stimulus’s spatial position. Normally, one would expect than in such a case of neural competition, a winner-take-all mechanism (Desimone, 1996; Lee et al., 1999; Reynolds and Desimone, 1999) would settle for a single perceptual interpretation of the stimulus (e.g., the illusory

colour). Yet, synaesthetes can report seeing both colours at once; in other words, “a single feature gives rise to two different qualia” (Treisman, 2005, p. 248). If one accepts this phenomenological report at face value, it follows that there is no winner between the illusory colour and the “real” colour and that both can become bound to the same shape. One possibility is that “increased connectivity” between neural networks of the synaesthete’s brain (Rouw and Scholte, 2007; Hänggi et al., 2008) might make possible such a dual perceptual experience. One can speculate that, at least for the synaesthetes, the multiple colour areas of the human brain may support in parallel different colour conscious experiences (cf. Zeki et al., 1999).

Specifically, we hypothesized that an increased distance in colour space between real and illusory colours will influence the degree of activity in colour-processing areas. That is, increased colour distance (CD) should result in increased processing of colour features, thus resulting in greater recruitment of neural units in V4/V8. Such a modulatory activity of the colours’ similarity could also be interpreted as evidence that multiple colours are simultaneously supported by the activity of colour-opponent neural cells within these visual areas (cf. Nikolich et al., 2007), so as to engender the simultaneous conscious experiences of more than one colour. In addition, based on previous neuroimaging studies of the Stroop task (e.g., Pardo et al., 1990; MacDonald et al., 2000; Gruber et al., 2002; Herd et al., 2006), one would expect that activity could be modulated by CD also in those areas that monitor the level of Stroop conflict.

In order to study the neural correlates of the simultaneous representations of two colours bound to the same stimulus or spatial position, we measured brain activity during the colour-word Stroop task (Stroop, 1935/2004) as well as single-letter variants of Stroop, with two grapheme-colour synaesthetes. Stroop tasks were chosen because in such tasks, both the relevant information (the target; e.g., the ink’s colour) in a task and the irrelevant information (the distractor; e.g., the meaning of the word or the synaesthetic colour) are parts of the same stimulus. Research has shown that it is extremely difficult to ignore the irrelevant information (MacLeod, 1991). The classic “Stroop effect” is characterized by naming errors and slowing of responses when words indicate different colours than the one in which they are printed (e.g., the word ‘blue’ is printed with red ink), compared to when they match. In such a task, it seems impossible to ignore the word, which automatically calls attention to another (conflicting) meaning and elicits the tendency to simply read out the (wrong) colour name.

Remarkably, synaesthetes can show Stroop interference with just single coloured letters (e.g., Mattingley et al., 2001; Paulsen and Laeng, 2006). This may happen because the name of the illusory colour of a letter may be automatically activated and this would compete with the name of the physical colour. Indeed, the illusory colour’s name should be for synaesthetes the first colour label to come to mind and especially so for “projector” than for “associator” synaesthetes (i.e., respectively, those synaesthetes who report perceptual-like colour sensations that are localized in external space vs those who experience the colours within an “inner space” or with the “mind’s eye”; Dixon et al., 2004).

Download English Version:

<https://daneshyari.com/en/article/10463362>

Download Persian Version:

<https://daneshyari.com/article/10463362>

[Daneshyari.com](https://daneshyari.com)