NOTE

PRESERVED IMAGERY FOR COLOURS IN A PATIENT WITH CEREBRAL ACHROMATOPSIA

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Abstract

We report the case of a patient who, after sequential bilateral strokes in the occipital regions sparing the primary visual cortex, developed a severe deficit of colour perception. At variance with other reports of acquired achromatopsic patients, she showed a perfectly vivid visual imagery for colours. These findings, together with similar data in domains other than colour processing, challenge the theories which posit that the same cognitive processes are involved in both the perception and the retrieval from memory of a given stimulus.

Introduction

Cerebral achromatopsia is an uncommon disorder of colour perception resulting from lesions in the anterior inferior part of the occipital lobe (Meadows, 1974). Patients typically complain that they cannot see colours anymore, and the world appears uniformly grey or brown. In the case of unilateral lesion achromatopsia is confined to the contralateral visual hemifield (see Zeki, 1990, for review).

According to some authors (Farah, 1988; Damasio, 1989), this perceptual deficit is always associated with an inability to recall the colour of common objects from memory (e.g., a tangerine, a poppy), a task which is often solved by imagining the relevant object in colour. Farah (1988) reviewed several case studies of acquired achromatopsic patients. She found a consistent association between impaired colour vision and impaired colour imagery, and concluded that the same neural representations are involved in seeing colours and imagining them. Additional evidence of the association between perception and imagery deficits in colour processing was provided by Damasio, Yamada, Damasio et al. (1980, case 2), Gomori and Hawryluk (1984), Levine, Warach and Farah (1985, patient 1), Rizzo, Smith, Pokorny et al. (1993), Goldenberg (1992), and Shelton, Bowers, Duara et al. (1994). These findings obtained in single-case studies are corroborated by the results of De Renzi and Spinnler (1967), who found a consistent association between "colour amnesia" (i.e., the inability to retrieve from memory the colour of an object) and perceptual colour processing deficits in an unselected group of unilaterally brain-damaged patients. The authors concluded that a deficit of colour revisualization was almost always present in patients with impaired colour perception.

However, this association of deficits is far from being the rule. Patients have been described with impaired mental colour imagery and preserved colour perception, thus suggesting a possible image generation deficit (see Goldenberg, 1993, for review). Possible instances of the opposite dissociation, namely colour perceptual deficit with intact colour imagery, have also been reported. The patient described by Meadows (1974, appendix; Pearlman, Birch and Meadows, 1979) was able to name the colours of common objects either spoken by the examiner or presented as black and white images. Also other

achromatopsic patients had no difficulty in naming the colours of common objects from memory (Green and Lessell, 1977; Heywood, Wilson and Cowey, 1987; Scarpatetti, Ketz and Jung, 1983). It must be noted, however, that in these studies the results of colour imagery tests are only cursorily reported, and all details on the questions are not given. This is a crucial point, since these patients' good performance could rely on a verbal association strategy rather than on the inspection of centrally generated images. Indeed, the colour of the items provided as examples by Meadows (grass, banana, fire-engine, London bus) may be recalled using verbal semantic knowledge. That achromatopsic patients can use a verbal strategy to answer colour-from-memory questions is strongly suggested by the report of a Belgian achromatopsic patient of Italian origin (Dumont, Griggio, Dupont et al., 1981). She enumerated in Italian the colours of the Italian flag, but was not able to say the colours of the Belgian flag, although she had been living in Belgium for decades. A more direct demonstration of the use of different strategies in these tasks was provided by Beauvois and Saillant (1985), whose patient R.V. was better in retrieving colour names using verbal strategies than using visual imagery, even when the same colour was concerned (e.g., R.V. was better on question like "what do people say when asked what colour snow is?" than answering questions like "imagine a beautiful snowy landscape... Can you see it? Well, now tell me what colour the snow is"). A similar dissociation was described by De Vreese (1991, case II).

Unequivocal evidence of a dissociation between perceptual colour processing and colour imagery abilities is provided by the present case study[1].

Case Report

Madame D is a 74-year-old right-handed housewife who had worked as a secretary and loved painting in oils as a hobby. She suffered in May 1995 from a haematoma located across the left temporo-occipital sulcus, involving the middle occipital gyrus and the inferior temporal gyrus (Brodmann areas 18, 19 and 37). She presented with a right homonymous

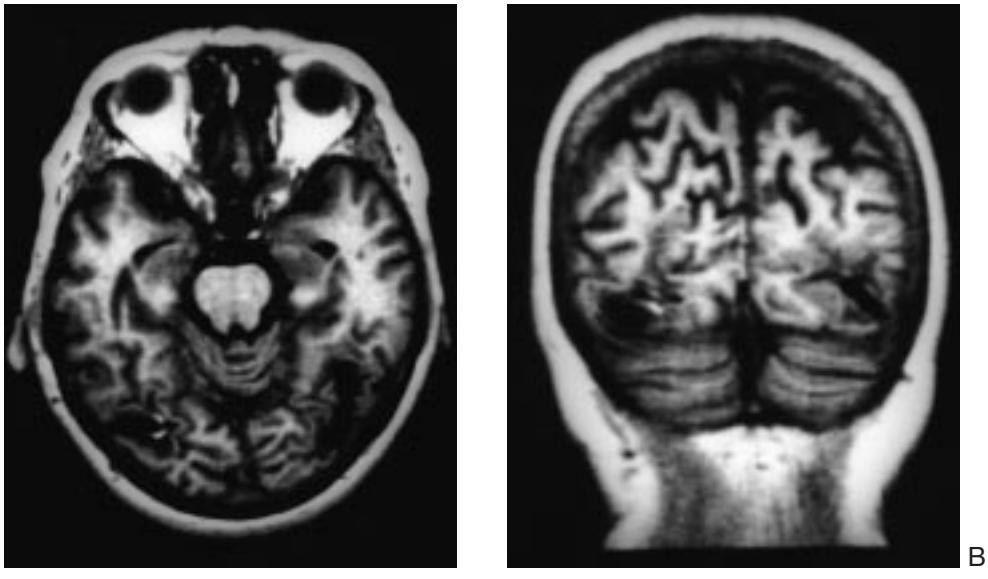

Fig. 1 – *T1 weighted MRI showing a left-sided lesion tying across the temporo-occipital sulcus and a right-sided lesion centred on the middle occipital gyrus.*

[1] Since submission of this paper, an achromatopsic patient has been described (Shuren, Brott, Schefft et al., 1996) with an unquestionable preservation of mental imagery for colours.

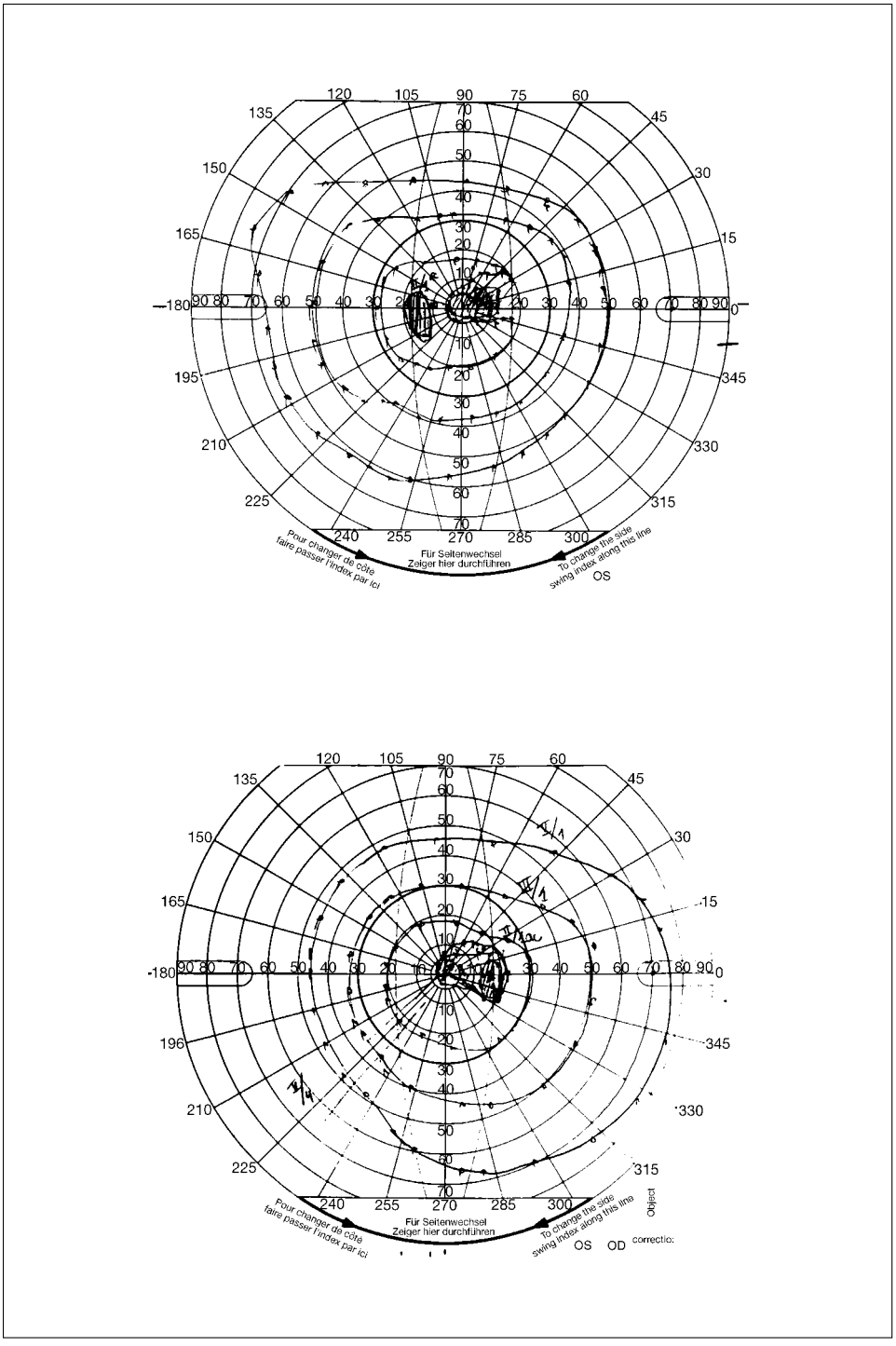

Fig. 2 – *Goldmann perimetry showing a central scotoma with II/4 testing.*

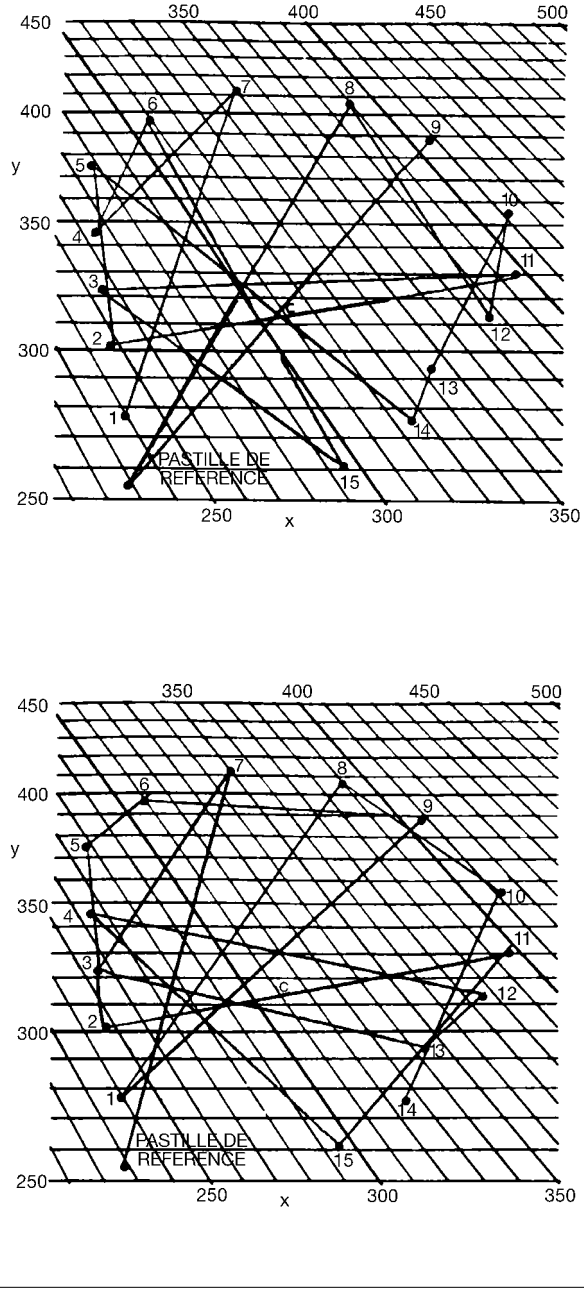

Fig. 3 – *Mme D's performance on the Farnsworth (1947) dichotomous test. Normal subjects' diagram follows the contours. Colour-blind subjects' performance is characterised by two or more lines crossing the diagram. The lack of any definite confusion axes is a frequent feature in cerebral, as opposed to congenital, achromatopsia (see, e.g., McCarthy and Warrington, 1990; Meadows, 1974).*

hemianopia and showed a mild anomia, without any comprehension or repetition deficit, that subsided after some weeks. No other linguistic deficits were present, apart from a pure alexia (which will be the focus of a subsequent article). After some weeks, her visual field defect had resolved on confrontation testing. Goldmann perimetry showed a residual right paracentral scotoma, which disappeared with IV/4 test. She named correctly and without hesitation 20 colours (see below, *Colour Naming*, for description of the test material). Colour identification in the right visual hemifield was also flawless on clinical testing: The colour of 4×4 cm colour patches presented at about 30° to the right of fixation on the horizontal midline was identified rapidly and without errors. At that time, Mme D's only complain was her reading difficulty. Since she could not enjoy reading anymore, Mme D occupied herself almost exclusively by painting. At that time, she never complained about problems with colours or colour mixtures.

In December 1995 she suffered from a second, right-sided haematoma, almost symmetrical to the first. The lesion was centred to the middle occipital gyrus, just posteriorly to the temporo-occipital sulcus. It involved area 19 and the white matter underlying area 18 (Figure 1). After the occurrence of the second stroke, Mme D found herself unable to recognise familiar faces and common objects by sight, and complained of seeing the world in shades of grey. She had full visual field on confrontation testing. Goldmann perimetry showed a central scotoma with II/4 test (Figure 2). Visual evoked responses with black and white pattern were normal for latency and amplitude. Mme D obtained a verbal IQ of 109 on the WAIS-R. She performed at chance level on a modified version of the Efron test (Warrington and James, 1988) and on the shape detection screening test of the Visual Object and Space Perception Battery (Warrington and James, 1991). She was unable to name any black-and-white realistic drawings. When asked to name real objects presented by the examiner, she was 13/35 correct on visual presentation, claiming that she was unable to recognise the other items. Examples of wrong responses in this task include *ring* → "coin", *telephone* → "wall diary", *glass* → "alarm clock". She correctly named the same objects when they produced some noise (e.g., jiggling keys) or on tactile presentation.

Formal colour testing began on February, 1996. By that time, Mme D claimed that her visual world had changed from grey to a reddish-brownish appearance, and reported to have occasionally perceived bright, saturated colours (e.g., she correctly identified the red of a truck moving on the road).

Perceptual Colour Testing

Colour Discrimination

The Farnsworth D-15 test (Farnsworth, 1947) was administered on two different occasions. The patient's performance was grossly defective (Figure 3). Mme D was well aware of her difficulties, and looked at each patch for a long time before arranging it. She never attempted to name the colours of the patches.

Mme D correctly identified the first and last items of the Ishihara (1974) plates, as colour-blind subjects can do. She was permitted to follow the targets' contour of the other items with her index finger, on account of her alexia. She found the task difficult, and outlined correctly 7 targets (items 2, 3, 9, 15, 16, 17). This result indicates a pathological performance.

Colour Matching

The patient was presented with a 16×20 cm board composed of 20 4×4 cm different colour patches and 20 separate 4×4 cm colour patches that she had to match with the corresponding colours on the board. Again she looked puzzled and performed the test slowly and hesitantly. She was 6/20 correct, when matching the orange, white, sky blue, dark green, royal blue and light brown patches.

Colour Pointing

Mme D was asked to point to the colours spoken by the examiner. The same plate was used as in the preceding test. The patient was 8/20 correct, when pointing to the green, black, orange, chestnut brown, white, dark green, royal blue and pink patches.

Colour Naming

Mme D was shown the same colour board and asked to name the colour pointed by the examiner. The test was administered twice on different days. As with the previously described tests, she was slow and hesitant in responding, carefully examining the patches and often expressing doubts about her responses. Occasionally, she remarked that colours changed in hue before her eyes. The overall correct performance was 8/40. In half of the cases the patient perseverated on some colour names (*beige* nine times, *green* seven times, *yellow* and *brown* four times). Names of the colour stimuli and patient's responses on the two test sessions are reported in the Appendix.

Mme D showed the same degree of impairment on naming, matching and pointing to colours ($\chi^2 = 2.76$, d.f. = 2, p n.s.). A qualitative comparison among the results of colour perceptual tests does not seem to suggest any consistent patterns of impairment on particular colours. For example, while green appeared to be relatively spared in some tests (it was correctly pointed at, it was named two times out of four, and it was present in all the identified items of the Ishihara plates), green patches were also erroneously arranged next to ochre, blue and violet in the Farnsworth test.

Colour Imagery Tasks

Colour Verbal Memory

Mme D was asked to say the appropriate colour of 20 objects indicated verbally by the examiner (De Renzi and Spinnler, 1967). She named quickly and correctly all the 20 colours, sometimes employing expressions that suggested the use of visual imagery rather than a verbal association strategy (e.g., *wheat* → "cream-coloured, pale yellow"). Equally flawless was the patient's performance on 15 items of the "verbo-visuo-verbal test" devised by Beauvois and Saillant (1985, appendix 3, experiment 2). Analysis of Mme D's responses suggested that she again relied on a mental imagery strategy (e.g., *interior part of a radish* → "white, with pale red streaks"; *champagne wine* → "it can be either pink or golden"; *pastis* → "opaline").

Colour-object Fluency (De Vreese, 1988)

The patient was asked to produce the name of as many objects as possible which are typically red, green, yellow and black. A time limit of 60 sec was allowed for each colour. Her score, 23 according to De Vreese's procedure, was largely higher than normative data (controls' mean score: 14.07 ± 3.98).

Colouyr Name Fluency (De Vreese, 1991)

Although this test does not necessarily require imagery abilities, it was administered to our patient in order to confirm the integrity of her colour lexicon. Mme D was asked to produce as many colour names as possible in 60 sec. She produced 14 colour names (controls' mean score: 10.41 ± 2.15).

Mental Hue Comparison

A modified version of a test devised by De Vreese (1991) was developed. Twenty-five pairs of items were proposed verbally by the examiner. Each pair was composed of objects of the same colour with a different hue (e.g., French bean/bay leaf, interior of a pineapple/ interior of a potato, cherries/strawberries, Paris metro ticket/pine). The patient was asked to say which of the items within a pair was darker in colour. Mme D was 24/25 correct. The only response that was considered as wrong was "potatoes are darker than chestnuts". On subsequent questioning, the patient explained that chestnuts are shiny, while potatoes are brown with a dull grey appearance.

DISCUSSION

Here we have reported the case of a patient who developed full-field achromatopsia following sequential bilateral occipital lesions. In fact, the symptom was not present following the first, left-sided occipito-temporal lesion, but it appeared when a second, symmetrical lesion in the right occipital cortex occurred. This puzzling sequence of events is difficult to reconcile both with the well known case descriptions of hemiachromatopsia due to unilateral lesion and with PET studies reporting a response to colour stimuli larger on the left than on the right side (Corbetta, Miezin, Dobmeyer et al., 1990; Lueck, Zeki, Friston et al., 1989; Zeki, Watson, Lueck et al., 1990). A subclinical hemi- or free field achromatopsia after the first left-sided occipital lesion cannot be excluded, but it would be surprising, given the pleasure that Mme D found in painting at that tirne. More in general, our data could support the notion of a critical role of the right hemisphere in colour processing (see, e.g., De Renzi and Spinnler, 1967; Davidoff, 1991).

Our patient's pattern of performance is relevant as concerns the relationship between perceptual and imagery processes. Visual imagery deficits often parallel visual perceptual deficits in the same domain. This observation led some authors (Damasio, 1989; Farah, 1988, 1989; Kosslyn, 1994) to postulate a common neural substrate for perception and imagery, i.e., specialised, domain-specific cortical areas would be used to process the same kind of information (e.g., colours) in perception and retrieval from memory.

However, perceptual and imagery deficits can dissociate one from another in several domains. Visual imagery can be spared in cases of cortical blindness (Chatterjee and Southwood, 1995; Goldenberg, Mullbacher and Nowak, 1995) and object agnosia (Behrmann, Moscovitch and Winocur, 1994; Servos and Goodale, 1995), and Behrmann et al.'s metanalysis of previous reports makes the case for a double dissociation between perceptual and imagery deficits of objects. Perri, Bartolomeo and Silveri (1996) described a pure alexic patient who showed a perceptual deficit of letter identification in the absence of any deficit of visual imagery for letters. Also prosopagnosic patients can be able to imagine faces (Hécaen, Ajuriaguerra, Magis et al., 1952).

Moreover, dissociations between performance on visual and imagery tasks can be observed in patients with unilateral spatial neglect (Anderson, 1993). In a group study, Bartolomeo, D'Erme and Gainotti (1994) found that only a minority of visual neglect patients showed signs of neglect on description from memory of familiar places (a task devised by Bisiach and Luzzatti, 1978). Moreover, the possibility exists of an imaginal neglect in the absence of, or after recovery from, visuospatial neglect (Bartolomeo et al., 1994; D'Erm, Bartolomeo and Gainotti, 1994; Guariglia, Padovani, Pantano et al., 1993).

In Kosslyn's (1994) and Farah's (1984) models, colour perception and colour imagery share a common visual buffer, in which both mental and physical colour percepts occur. Through a generation process, the content of long-term memory is transferred onto the visual buffer, where it can be inspected for further processing. According to this model, a selective deficit of the generation process should result in impaired imagery coupled with intact perception (recognition would be possible through a direct access to long-term memory representations) (Farah, 1984).

The opposite dissociation, namely impaired perception and intact imagery, should occur following a deficit of perceptual access to intact visual representations. In Kosslyn's words, "problems in perceptual organization or in matching input to stored visual representations in the pattern activation subsystems can impair perception but leave imagery relatively intact (1994, p. 329)". In our patient, however, visual imagery for colours was not only "relatively" spared, but perfectly vivid, despite a striking impairment of colour perception. The hypothesis of a problem of matching between visual input and stored visual representations does not fit with the clinical reality of Mme D's perception of the world as drained of colours, and her inability not only to identify but also to discriminate between colours. According to Kosslyn (1994), the visual buffer is a structure in the occipital lobe, composed of retinotopically organised areas from V1 to V4. An impairment of early sensory analysis (i.e., from the retina to V1) can be reasonably ruled out in our patient, given the lack of clinical, neuroradiological and neurophysiological evidence of damage to the visual system prior to the extrastriate areas (apart from the small visual field deficit, which obviously cannot account

for the achromatopsia). Assuming Kosslyn's model, the functional locus of impairment in our patient should be at the level of the visual buffer, challenging the claim (Farah, 1984; Kosslyn, 1994) that a single visual buffer constitutes the common "screen" for perceptual and imagery processes.

From the anatomo-functional point of view, our patient's pattern of spared colour memories in the absence of colour perception does not easily accommodate with Damasio's (1989) hypothesis that memory contents are retrieved through the retroactivation of the very same cortical areas that had processed the revelant information during perception. These "early cortices" include the primary and first-order associative sensory cortices. According to Damasio, "no other cortices, and certainly no other higher order, integrative cortices, are capable of supporting the recall of the perceptually impaired feature (1989, p. 33)". Our patient's achromatopsia can be explained either by direct damage to a cortical area specialised for colour processing (possibly the human homologue of V4, located in the prestriate cortex [Corbetta, Miezin, Dobmeyer et al., 1990; Zeki, Watson, Lueck et al., 1990]), or by a disconnection of V4 from the primary visual areas (V 1). In the first case, Damasio's hypothesis is directly disconfirmed. As for the hypothesis of a disconnection between intact V4 and V1 areas, it explains Mme D's pattern of impairment. But even in this case a difficulty arises with Damasio's hypothesis. According to Damasio, Mme D's vivid visual memories should depend on the retroactivation of V1, but this would be an implausible mechanism if this area were disconnected from more anterior areas, such as V4.

Our case can be explained in a much easier way by postulating different cortical implementations of perceptual and imagery colour processing. In a PET experiment (Martin, Haxby, Lalonde et al., 1995), subjects had to generate the name of colours associated with an achromatic line drawing of an object, or with its written name. In both conditions, a region was activated in the ventral temporal lobe, 2 to 3 cm anterior to the region of the fusiform gyrus activated by colour perception (Corbetta et al., 1990; Zeki et al., 1993). Provided that subjects used a colour-imagery strategy to perform the task, the data would suggest that distinct cortical regions are implied in perceptual analysis and imagery of colours. The fact that these cortical areas lie close to one another would make them liable to be damaged at the same time, thus accounting for the frequent observation of an association between perceptual and imagery deficits in colour processing.

Additional support for this interpretation of our patient's pattern of performance comes from the report (Luzzatti and Davidoff, 1994) of two patients with the opposite dissociation to the one showed by Mme D. These two patients had preserved colour perception and impaired retrieval of knowledge concerning the colours of objects. Interestingly, their lesions, caused by herpes simplex encephalitis, appeared to affect regions anterior to the location of Mme D's lesions.

The possibility that perception and imagery are implemented in distinct cortical areas is a disappointing one for those of us who followed with interest the attempts to establish a neural equivalence between the two processes. Nevertheless, this possibility is reassuring in that it seems to confirm common experience: That seeing something for real is quite different from imagining it – unless, of course, one suffers from hallucinations.

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APPENDIX

Responses Produced by Mme D on the Colour Naming Test

Stimulus	1st session	2nd session
Green	Beige	+
Red	Pink, not red	+
Black	Grey or brown	Brown
Orange	Light beige	Red
Mauve	Dark beige	Brown
Chestnut brown	Green	Grey
Pale yellow	Beige	Pink
Violet	Light brown	Red
Ochre	Dark yellow	Brown
White	Light yellow	Pink
Crimson	No answer	Dark red (+)
Yellow	Yellow (+), beige	Yellow, grey, yellow (+)
Golden yellow	Beige	Ochre
Pastel green	Blue	Blue
Sky blue	Blue-green	Green
Dark green	Green (+)	Grey
Royal blue	Green	+
Dark grey	Green	Grey-beige
Light brown	Beige (+)	Orange
Pink	Beige	Green