ELSEVIER

Neuropsychologia 44 (2006) 1437–1443

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Covert colour processing in colour agnosia

Tanja C.W. Nijboer*, Martine J.E. van Zandvoort, Edward H.F. de Haan

Psychological Laboratory, Helmholtz Instituut, Universiteit Utrecht Heidelberglaan 2, NL-3584 CS Utrecht, The Netherlands

Received 9 September 2005; received in revised form 4 December 2005; accepted 8 December 2005
Available online 18 January 2006

Abstract

Patients with colour agnosia can perceive colours and are able to match coloured patches on hue, but are unable to identify or categorise colours. It is a rare condition and there is as yet no agreement on the clinical definition or a generally accepted explanation. In line with observations from object agnosia and prosopagnosia, we hypothesised that (some of) these patients might still be able to process colour information at an implicit level. In this study, we investigated this possibility of implicit access to colour semantics and colour names in a man (MAH) who suffers from developmental colour agnosia. We designed two experimental computer tasks: an associative colour priming task with a lexical decision response and a reversed Stroop task. The results of these experiments suggest that there is indeed automatic processing of colour, although MAH was unable to explicitly use colour information.

Keywords: Implicit colour knowledge; Colour priming; Reversed Stroop interference

1. Introduction

Colour vision is a powerful aide for distinguishing and identifying objects. It enriches subjective visual experience and enables object- and pattern recognition, especially when the object possesses characteristic or 'diagnostic' colours.

The cortical processing of colour fractionates into a number of specific sub-processes, each with their own neuro-anatomical substrates. Humans have the ability to match, classify, name, memorise and imagine colour. Each of these abilities can be lost as a result of brain damage and the occurrence and the co-occurrence of deficits suggest that each may be functionally independent. Neuropsychological studies have demonstrated selective colour impairments, e.g. cerebral achromatopsia (selective impairment in colour perception; e.g. Heywood & Cowey, 1999; Meadows, 1974; for review, see Zeki, 1990), colour agnosia (selective impairment in colour recognition; e.g. Beauvois & Saillant, 1985; Davidoff, 1996), and colour anomia (selective impairment in colour naming; e.g. Davidoff & Ostergaard, 1984; Geschwind & Fusillo, 1966). In this paper, we will focus on colour agnosia.

One of the first clinical descriptions of patients with a selective impairment in retrieving the colour of familiar objects was reported by Lewandowsky (1908); (for translation, see Davidoff & Fodor, 1989). This patient could not name or indicate the colour of objects, even when presented with the object name or an uncoloured drawing. He also experienced problems in sorting colours, and naming or pointing to colours that were named by the examiner. Lewandowsky (1908) attributed the dissociation of colour and form to colour anomia, a view shared by Damasio, McKee, and Damasio (1979). Colour agnosia is often accompanied by alexia and homonymous hemianopia (Beauvois & Saillant, 1985; Woodward, Dixon, Mullen, Christensen, & Bub, 1999). However, others have suggested that colour agnosia can result from a disturbed access to the colour lexicon or to imagery disturbances (Beauvois & Saillant, 1985; de Vreese, 1991).

Poor object-colour retrieval with good colour naming is very rare. Beauvois and Saillant (1985) studied two patients with visual, verbal and visuo-verbal tests and differentiated two syndromes: colour agnosia (specific impairments on the visual tests) and optic aphasia for colours (specific impairments on the visuo-verbal tests). Further dissociations have been found between poor object-colour retrieval with preserved ability to categorise colours and to name colours (e.g. Beauvois & Saillant, 1985) and without the ability to name colours (Levine, 1978). This shows that knowledge about colour is neither strictly verbal nor visual. The suggestion that colour agnosia may not be a unitary con-

* Corresponding author.
E-mail address: t.c.w.nijboer@fss.uu.nl (T.C.W. Nijboer).

0028-3932/$ – see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2005.12.004

dition has strengthened by the work of Luzzatti and Davidoff (1994). They reported two patients who could name colours, but could not associate a colour with an object. Moreover, they had no problem with naming fruits and vegetables. The authors argued that these patients suffered from selective impairments in object-colour knowledge and that impairment in retrieving object-colour knowledge did not necessarily impair naming performance for categories of living objects, such as fruits and vegetables. This latter view was put forward by Warrington and Shallice (1984). Miceli, Fouch, and Capasso (2001) reported a patient who had a selective impairment in object-colour knowledge, but was able to arrange, recognise and name coloured patches, and had intact knowledge about object form, size and function. These three examples indicate a functional independence between colour knowledge and object-colour knowledge.

In summary, patients with colour agnosia can perceive colours and are able to match coloured patches on hue, but are unable to identify or categorise colours. Moreover, they often cannot name or indicate the colour of familiar objects. This inability is not caused by memory or language deficits and these patients have intact conceptual knowledge of objects (Davidoff, 1991). Overall, three conclusions can be drawn: first, colour agnosia is not a unitary disorder; second, there is no agreement on a proper clinical definition; third, there is no generally accepted explanation.

Although patients with colour agnosia do not have explicit access to colour knowledge, it is unclear whether there might be any implicit colour processing. In many neuropsychological disorders, it has become clear that despite the absence of 'acknowledged awareness' preserved information processing can be demonstrated (Schacter, McAndrews, & Moscovitch, 1988). Implicit knowledge has been observed in patients with visual field defects ('blindsight': Weiskrantz, Cowey, & Barbur, 1999; Weiskrantz, Warrington, Sanders, & Marshall, 1974), object agnosia, a disorder in which patients have difficulty perceiving and recognising visual objects (Goodale, Milner, Jakobson, & Carey, 1991) and prosopagnosia, the impaired ability to recognise familiar faces (Bauer, 1984; de Haan, Bauer, & Greve, 1992; de Haan, Young, & Newcombe, 1991; Tranel & Damasio, 1985). The key element of the distinction between explicit and implicit cognitive processing is the presence or absence of awareness.

Analogous to observations in amnesia and prosopagnosia, we hypothesised that (some of) the colour agnosia patients might still be able to process colour information at an implicit level. In this study, we used two experimental tasks: an associative colour priming task with a lexical decision response and a reversed Stroop task. Priming paradigms are among the most frequently used methods for studying implicit information processing. Priming effects have been observed even in the total absence of recall or recognition. It has been suggested that repetition priming effects depend on changes in the perceptual representation systems that preserve information about the form and structure, but not the meaning and associative properties of words and objects. Associative priming on the other hand, is taken as an effect that is derived from the level of processing where meaning is accessed (e.g. Neely, 1977) This latter task is well suited for studying covert processing. Another useful experimental procedure for studying covert effects concerns interference or 'Stroop' tasks. The classical Stroop effect is demonstrated by asking subjects to name the hue of colour words printed in incongruent ink colour. The Stroop interference effect is a very robust effect and replicable for a variety of stimulus materials and experimental tasks (see MacLeod, 1991, for a comprehensive overview). As patients with colour agnosia have difficulties naming colours, we needed to change the standard Stroop paradigm. In the standard Stroop interference task, hardly any interference is found when participants read a colour name printed in an incongruent colour, so we reduced readability by making the 'ink colour' equiluminant to the background. The observation of a reversed Stroop effect would indicate covert processing of colour not only at the level of access to semantics, as in the associative priming, but also at the level of colour words.

With these two tasks, we are able to test implicit processing at two different levels. The priming tasks measures access to object-colour associations, at the level of structural knowledge of objects and semantics, whereas the Stroop interference task measures access to colour-name associations, at the level of assigning correct names to colours. It has been argued that category-specific problems may arise from damage to different components of the object recognition system. Some patients have problems accessing stored structural knowledge of objects (e.g. Sartori & Job, 1988), whereas others may have difficulty accessing semantic information about objects (e.g. Hillis & Caramazza, 1991) and still others are unable to access the correct name for objects (e.g. Farah & Wallace, 1992).

1.1. Case report

MAH is a 44-year-old male who came to our attention when he was included in a longitudinal research project on the cognitive sequelea following a stroke. Patient MAH has been reported in detail elsewhere (van Zandvoort, Nijboer, & de Haan, in press) and will be briefly summarised here. He had suffered a cerebellar infarct, and in the acute phase the neuropsychological assessment in the acute phase showed mild dizziness and subtle memory deficits. At follow-up, 2 years later, no cognitive consequences could be detected, and he did not have any residual complaints and fully returned to his pre-morbid occupational life. Overall, the neuropsychological assessment showed that MAH functions at a very high level of general intelligence with above average performances on memory, language, attention and executive tasks.

However, during the initial neuropsychological assessment, while administrating the token test for language comprehension, it became apparent that he could not name the coloured tokens. This observation was in stark contrast to his faultless performance on the Ishihara test for colour blindness (1971). His intact colour perception was subsequently confirmed on the Farnsworth–Munsell 100 hue test Farnsworth (1942). The diagnosis of colour agnosia was established on the basis of his inability to reliably name the hue of standard coloured tokens (pencils). In addition, he performed at chance-level on a task