SPECIAL SECTION

2D BUT NOT 3D: PICTORIAL-DEPTH DEFICITS IN A CASE OF VISUAL AGNOSIA

Oliver H. Turnbull[1]**, Jon Driver**[2] **and Rosaleen A. McCarthy**[3]

([1]School of Psychology, University of Wales, Bangor, UK; [2]Institute of Cognitive Neuroscience and Department of Psychology, University College London, UK; [3]Department of Experimental Psychology, University of Cambridge, UK)

Abstract

Patients with visual agnosia exhibit acquired impairments in visual object recognition, that may or may not involve deficits in low-level perceptual abilities. Here we report a case (patient DM) who after head injury presented with object-recognition deficits. He still appears able to extract 2D information from the visual world in a relatively intact manner; but his ability to extract pictorial information about 3D object-structure is greatly compromised. His copying of line drawings is relatively good, and he is accurate and shows apparently normal mental rotation when matching or judging objects tilted in the picture-plane. But he performs poorly on a variety of tasks requiring 3D representations to be derived from 2D stimuli, including: performing mental rotation in depth, rather than in the picture-plane; judging the relative depth of two regions depicted in line-drawings of objects; and deciding whether a line-drawing represents an object that is 'impossible' in 3D. Interestingly, DM failed to show several visual illusions experienced by normals (Muller-Lyer and Ponzo), that some authors have attributed to pictorial depth cues. Taken together, these findings indicate a deficit in achieving 3D intepretations of objects from 2D pictorial cues, that may contribute to object-recognition problems in agnosia.

Key words: pictorial depth, agnosia, object recognition, 2D, 3D

Introduction

The period spanned by Ennio De Renzi's inspirational career has seen an enormous growth in our understanding of vision and its neurobiological basis, due in part to single-cell recording methods and more recent technical developments such as functional imaging, but also due to the careful study of neuropsychological deficits after brain injury in neurological patients, as pioneered by De Renzi. As regards theory, the recent decades also have seen an increasing understanding of the importance of regional specialization - in domains such as spatial cognition, object recognition, and visually-guided action (Farah, 1990; Grusser and Landis, 1991; Milner and Goodale, 1995), together with an understanding that small-scale 'modules' are typically part of wider patterns of cortical organization, and form interacting components of widespread networks (Milner and Goodale, 1995; Ungerleider and Mishkin, 1982; see also Cowey, 1981). De Renzi has of course made seminal contributions to virtually every domain of neuropsychology alluded to above, across several decades (e.g. De Renzi and Faglioni, 1967, to De Renzi and Di Pellegrino, 1998) - though his work is perhaps most accessibly known from his classic monograph (De Renzi, 1982)

The extent of progress in understanding the neuropsychology of vision has been far from uniform, however, and there are several apparently important topics that may have been under-investigated to date. One such topic is visual depth perception: and in particular the question of how three dimensions are extracted from two-dimensional images. There is an extensive psychological literature on this topic (Gibson, 1966; Gregory, 1966; Julesz, 1971; Rock, 1973), but rather less in the way of neuropsychology (see Carey et al., 1998). De Renzi's (1982) classic text covers the issue of depth perception in only two brief sections (pp. 60-63 and pp. 141-145). Nevertheless, in reviewing the literature two decades ago, De Renzi characteristically foreshadowed a number of issues that have since become more widely recognised (e.g. Turnbull, 1999). For example, De Renzi warned of the potential risks of designating disorders as being of exclusively perceptual origin, when the findings might also involve motor processes, as when a 'depth' deficit is evident only in action (e.g. in distance errors when misreaching, De Renzi, 1982, p.141).

De Renzi (1982) also commented on the likely anatomy of disorders in depth processing. He noted (pp.141-145) that the most common lesion sites implicated by these deficits seemed to involve the occipital and/or parietal lobes (i.e. including dorsal rather than ventral pathways). The more recent literature, as reviewed by Carey et al. (1998), contains only a limited number of neuropsychological studies on depth, which mainly approached the problem from the 'perception versus action' perspective of Milner and Goodale (1995), and have focused primarily on the dorsal 'visuo-motor' stream. Thus, recent studies have tended to focus on the role of depth information in the processing of relative or absolute distance, as evidenced in either perceptual judgements or else in the biomechanics of reaching, grasping and catching, with binocular versus monocular cues being compared (see Haffenden and Goodale, 1999; Mon-Williams and Dijkerman, 1999; Marotta et al., 1997; Mon-Williams et al., 2001; Servos et al., 1992; Servos and Goodale, 1998). The main thrust of this literature has been in general agreement with De Renzi's (1982) proposal that binocular depth information may be useful in the control of spatial action (see also Dijkerman et al., 1996; Gallese et al. 1995, Otto-de Haart et al., 1999, Marotta et al., 1998), by the dorsal stream. Any possible role for pictorial cues to depth processing in the ventral (occipito-temporal) stream appears to have been less studied by neuropsychologists in recent years, at least within the literature inspired by the dorsal/ventral dichotomy. However, in mainstream psychology it has often been argued that pictorial cues to distance might have major impacts on perceptual processes, as in size-constancy (e.g. Gibson, 1966) and in potentially related illusions of size (e.g. Gregory, 1966).

We turn now to consider the possible role of pictorial depth-cues in 'visual agnosia', the generic term for acquired neurological disorders of object-recognition (see Farah, 1990; Grusser and Landis, 1991; Humphreys and Riddoch, 1987 for reviews). Some forms of brain-damage (typically affecting occipito-temporal cortex, in the ventral stream) can disrupt visual object recognition, while leaving 'elementary' vision (brightness, acuity, colour, motion) fairly intact. Recognition by touch, sound, or verbal description may also be preserved (see De Renzi, 1982; Farah, 1990; Grusser and Landis, 1991). Many patients diagnosed on this basis as suffering from visual agnosia are described as apparently having access to a fairly accurate description of the structural properties of the visual objects before them, which they cannot recognise. Lissauer (1890) originally distinguished between 'apperceptive' disorders (for patients in whom there was some fundamental perceptual deficit in perceiving shape, as apparent for instance in their inability to match or copy simple shapes), versus those with 'associative' impairment, in whom low level perception was apparently intact. Teuber (1968) elegantly described associative agnosics as having "a normal percept stripped of its meaning". However, it has since been argued that many patients who would classically have been diagnosed as associative agnosics may in fact have subtle 'high-level' perceptual impairments that disrupt the full extraction of object structure (e.g. see Farah, 1990; Humphreys and Riddoch, 1987; Farah and Feinberg, 1997). It has also been noted by such authors that the traditional clinical test for intact structural perception in agnosic patients – namely a preserved ability to make accurate copies of seen line-drawings – may be inadequate.

It was in this context that Farah (1990, pp. 59-69) listed several lines of evidence which suggested that many cases of so-called 'associative' agnosics might in fact have some perceptual deficits in extracting object structure, despite preservation of elementary visual processes. While such patients may eventually produce relatively accurate copies of line drawings, in fact these may be produced in a pathologically 'slavish' and piecemeal manner (see also Humphreys and Riddoch, 1987). Moreover, one patient categorised as having associative visual agnosia (with apparently 'normal' copying) case M.S. of Ratcliffe and Newcombe (1982), was unable to classify line-drawings of the type introduced by Penrose and Penrose (1958) as 'possible' or 'impossible' in 3D. The 'impossible' versions among these stimuli depict perspective views which are very unlikely (Gregory, 1970) to correspond to a coherent three-dimensional object, because of inconsistencies in the pictorial depth information at various junctions on the shape (Cowan, 1974). We report a task based on such stimuli later in this paper (and an example can be observed in Figure 6). Distinguishing possible and impossible versions of these stimuli is trivial for normal observers, but this distinction was problematic for patient MS (Ratcliffe and Newcombe, 1982). Moreover, MS apparently took the same amount of time to copy both possible and impossible nonsense objects (Farah, 1990, p.63), whereas normal subjects are considerably faster to copy the possible objects, presumably as they can use the cues from coherent 3D structure to aid them.

Thus some patients with agnosic deficits, including some of those who would traditionally be classified as 'associative' on the basis of relatively preserved copying, may be restricted in their ability to obtain the appropriate 3D structure from the 2D cues available in line-drawings. Perhaps patients such as MS are able to extract 2D edge-based information in the image while the extraction of 3D structure from pictorial cues within the 2D image might be impaired. If so, this might demonstrate one form of spatial processing that might be specific to the representation of objects, having little or nothing to do with the various forms of 'depth' processing that have been associated with the dorsal stream in studies of visually-guided action (c.f. Carey et al., 1998).

In the remainder of this paper, we report the new case of a patient (DM) who suffers from visual agnosia following head-injury. He still appears able to extract stable 2D information from visual images; but his ability to extract 3D structure from the pictorial depth-cues within 2D images (e.g. line-drawings) is greatly compromised. This deficit in deriving 3D structure from pictorial