Abnormal visual phenomena in posterior cortical atrophy

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Individuals with posterior cortical atrophy (PCA) report a host of unusual and poorly explained visual disturbances. This preliminary report describes a single patient (CRO), and documents and investigates abnormally prolonged colour afterimages (concurrent and prolonged perception of colours complimentary to the colour of an observed stimulus), perceived motion of static stimuli, and better reading of small than large letters. We also evaluate CRO’s visual and vestibular functions in an effort to understand the origin of her experience of room tilt illusion, a disturbing phenomenon not previously observed in individuals with cortical degenerative disease. These visual symptoms are set in the context of a 4-year longitudinal neuropsychological and neuroimaging investigation of CRO’s visual and other cognitive skills. We hypothesise that prolonged colour after-images are attributable to relative sparing of V1 inhibitory interneurons; perceived motion of static stimuli reflects weak magnocellular function; better reading of small than large letters indicates a reduced effective field of vision; and room tilt illusion effects are caused by disordered integration of visual and vestibular information. This study contributes to the growing characterisation of PCA whose atypical early visual symptoms are often heterogeneous and frequently under-recognised.

Keywords: Posterior cortical atrophy (PCA); Alzheimer’s disease (AD); Reversal of vision metamorphopsia; Gaze instability; Colour perception.

INTRODUCTION

Posterior cortical atrophy (PCA) is a progressive neurodegenerative condition involving prominent tissue loss in the occipital, parietal and posterior temporal cortex. PCA is characterised by the progressive deterioration of higher visual processing and other posterior cortical functions, with first symptoms often occurring before the age of 65 (e.g., Benson, Davis, & Snyder, 1988; Cogan, 1985; De Renzi, 1986; Galton, Patterson, Xuereb, & Hodges, 2000). Alzheimer’s disease (AD) is the most common underlying pathology (Cogan, 1985; Rogelet, Delafosse, & Destee, 1996; Ross et al., 1996) and indeed the condition is often referred to as the ‘biparietal’ or ‘visual’ variant of AD, or alternatively as Benson’s syndrome after the original clinical description (Benson et al., 1988). The distinction between PCA and the typical amnestic presentation of AD reflects the distribution of the AD pathology. Individuals with PCA tend to have a much greater density of senile plaques and neurfibrillary tangles in occipital cortex and regions of posterior parietal cortex and temporo-occipital junction than those with typical AD, whilst showing fewer pathological changes in more anterior areas.
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(e.g., prefrontal cortex; Hof, Vogt, Bouras, & Morrison, 1997; Tang-Wai et al., 2004). These and other differences between PCA and typical AD may be underpinned partially by genetic risk factors in the ApoE ε4 allele, which is strongly associated with typical AD but which does not seem to be a risk factor in PCA (Schott et al., 2006; Snowden et al., 2007).

In accordance with the distribution of pathology and atrophy, patients with PCA tend to show relative sparing of many aspects of cognition such as memory and language and often have full insight into their condition. Thus in the early stages of the disease, they do not meet the standard diagnostic criteria for typical AD. Instead, the most prominent symptoms tend to include early visual processing deficits (e.g., achromatopsia, figure-ground discrimination problems), apperceptive agnosia, prosopagnosia, spatial deficits (e.g., visual disorientation, spatial agnosia) and other symptoms such as optic ataxia, gaze apraxia and limb apraxia (Benson et al., 1988; Freedman et al., 1991; Levine, Lee, & Fisher, 1993; McMonagle, Deering, Berliner, & Kertesz, 2006; Mendez, Ghajarania, & Perryman, 2002; Rogelet et al., 1996; Ross et al., 1996). Patients with PCA also experience other related and unrelated behavioural symptoms including dyslexia, acalculia, dysgraphia and visual inattention (see Caine, 2004 for a review).

However, in addition to these well-recognised neuropsychological deficits, patients with PCA also report a host of other symptoms, the anatomical and cognitive basis of which are much more poorly understood. For example, the tendency for patients with progressive visual disturbance (who might now be considered to have PCA) to have greater difficulty recognising large as compared with small pictures and other stimuli has been described (e.g., Pick, 1908 cited in Bender and Feldman, 1972; Coslett, Stark, Rajaram, & Saffran, 1995; Kartsounis and Warrington, 1991; Saffran, Fitzpatrick-DeSalme, & Coslett, 1990; Stark, Grafman, & Fertig, 1997). Another abnormal effect described previously in a patient with PCA is the experience of abnormal colour afterimages and washes of colour (e.g., Chan, Crutch, & Warrington, 2001). However, despite occasional reports, such unusual or atypical symptoms are often poorly recognised, and sometimes contribute to incorrect diagnoses of malingering, anxiety or ophthalmological disease in the earliest stages of the condition.

In this paper, we report a single patient with PCA who exhibits a number of unusual symptoms which are poorly recognised but nonetheless may prove to be characteristic of PCA. This preliminary report replicates evidence of prolonged colour afterimages and better reading of small than large letters, and describes two further abnormal visual phenomena, namely perceived motion of static stimuli and room tilt illusion effects. We argue that these cognitive phenomena should be targets for systematic evaluation in future cohort studies of PCA, and have significant implications for patients’ functional abilities.

**CLINICAL DESCRIPTION**

CRO is a right-handed retired health professional who was referred to the National Hospital in 2004 (aged 57 years old) with a 4-year history of progressive visual impairment. Early visual symptoms included difficulty in making depth and distance judgements, and the appearance of coloured patches at the edge of her visual field. Investigations conducted prior to referral included a brain MRI which was reported as normal, and an EEG showing poorly sustained alpha rhythm with temporal lobe slowing. Normal electroretinography (ERG) and visual evoked potentials (VEPs) investigations suggested normal retinal and optic nerve functions. Initial neuropsychological assessment also corroborated the clinical impression of predominant posterior cortical damage, with particular weaknesses on tests of visuo-spatial and visuoperceptual functions especially for complex stimuli. Visual inspection of a brain MRI indicated subtle biparietal atrophy but no hippocampal volume loss or vascular disease. There was no evidence of brainstem or cerebellar infarction on this or subsequent MRI scans, which included diffusion weighted imaging sequences.

Consequently, CRO was given a diagnosis of posterior cortical atrophy (PCA) owing to probable Alzheimer’s disease. This diagnosis was made on the grounds of the clinical information summarised above but also upon the fulfilment of behavioural criteria employed routinely at the Dementia Research Centre. These criteria require an individual to demonstrate memory function above the 5th percentile and at least 2 out 4 scores below the 5th percentile on the following 4 tests: Number location and Object Decision subtests from the Visual Object and Space Perception battery (VOSP; Warrington & James, 1991) and graded difficulty tests of arithmetic and spelling (Baxter & Warrington, 1994; Jackson & Warrington, 1986).
On further clinical examination in December 2009 (aged 62 years old), 8 years into her illness, she scored 21/30 on the Mini-Mental State Examination. Neurological examination revealed marked visual disorientation and difficulties with visual fixation and praxis. A full neuro-otological assessment including detailed eye movement examination was conducted at the time and is reported in section 7 (Room tilt illusion). She continued to have no limb myoclonus or extrapyramidal signs and her deep tendon reflexes were all depressed but symmetrical with flexor plantar responses. Sensory examination, including joint position sense, was normal throughout. There was no history of formed visual hallucinations, fluctuating cognition or symptoms of a REM sleep disorder to suggest Lewy body disease.

Written informed consent was obtained using procedures approved by the National Hospital for Neurology and Neurosurgery and Institute of Neurology Joint Research Ethics Committee.

LONGITUDINAL NEUROPSYCHOLOGICAL AND NEURORADIOLOGICAL EVIDENCE

CRO completed a neuropsychological assessment in August 2004, and then participated in several research visits before entering a clinical trial examining the effectiveness of the acetylcholinesterase inhibitor donepezil in posterior cortical atrophy between October 2004 and April 2005. Following completion of the trial, CRO attended for a series of 4 yearly research assessments between January 2006 and November 2008, each involving a neuropsychological assessment and a 1.5-T MRI scan.

The neuropsychological evaluation included measures of general cognitive function (Folstein et al., 1975), verbal recognition memory (Warrington, 1996), verbal synonym comprehension (Warrington et al., 1998), naming to verbal description, cognitive estimation (Shallice & Evans, 1978), and psychomotor speed (Willison & Warrington, 1992). A series of literacy (reading: James et al., 2001; spelling: Baxter & Warrington, 1986), numeracy (Jackson & Warrington, 1986), praxis (Crutch, 2004) and short-term memory tasks (digit span forwards) were also administered. Early visual processing was assessed using the Visual Acuity, Hue Discrimination and Visual Crowding subtests from the Cortical Visual Screening Test (CORVIST; James et al., 1991), the Shape Detection subtest from the Visual Object and Space Perception Battery (VOSP; Warrington & James, 1991), and a shape discrimination test (based on Efron, 1968). Visuoperceptual processing was examined using the VOSP Fragmented Letters and Object Decision subtests, and the canonical/non-canonical view perception test of Warrington and James (1988). Finally, visuospatial processing was investigated using the VOSP Number Location and Dot Counting subtests, and the Motor Screening test from the Cambridge Neuropsychological Test Automated Battery (CANTAB®, Cambridge Cognition).

The scores from the neuropsychological assessments are shown in Table 1. During the course of the 4-year interval between the first and last assessments, CRO continued to score in the normal range on tests of verbal recognition memory, word retrieval, word comprehension, spelling and visual acuity. It was noted though that her episodic memory and spelling skills in particular did show signs of deterioration during this period from their previously superior levels. CRO’s verbal short-term memory, upper limb praxis and cognitive estimation skills were also intact initially but were observed to be impaired at visits 3 and 4, whilst calculation was impaired at all assessments. Considering tasks with a visual component, CRO was observed to be significantly impaired on all tests of visuoperceptual and visuospatial processing from the outset of our investigations, with particularly poor performance of tasks involving the apperception of non-canonical, degraded and spatially dispersed stimuli. It is of note that at the baseline assessment, impoverished space and object apperception were contrasted with intact performance on a range of more basic, early visual processing tasks (shape detection, shape discrimination, hue discrimination). However, her early visual processing skills soon followed the deterioration in her higher order perceptual functioning with increasing difficulties on discrimination and visual crowding tasks over subsequent visits.

MRI scans were acquired on a 1.5-T GE Signa scanner (General Electric, Milwaukee, WI) using an inversion-recovery prepared fast SPGR sequence (TE = 5.4 ms, TR = 12 ms, TI = 650 ms). T1-weighted volumetric images were obtained with a 24-cm field of view and 256 × 256 matrix to provide 124 contiguous 1.5-mm thick slices in the coronal plane. All scans were corrected for intensity inhomogeneities using the N3 algorithm (Sled, Zijdenbos, & Evans, 1998). Each repeat was
### TABLE 1

Performance on background neuropsychological tests, including verbal memory, word retrieval and comprehension, frontal-executive skills, literacy, numeracy, and early visual, visuoperceptual and visuospatial processing

<table>
<thead>
<tr>
<th>TEST</th>
<th>Baseline</th>
<th>Aug 04–Jan 05</th>
<th>Visit 1 Jan 06</th>
<th>Visit 2 Jan 07</th>
<th>Visit 3 Jan 08</th>
<th>Visit 4 Nov 08</th>
<th>Norms/comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE&lt;sup&gt;1&lt;/sup&gt;</td>
<td>28/30</td>
<td>28/30</td>
<td>25/30</td>
<td>23/30</td>
<td>Normal range: ~27–30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short Recognition Memory Test&lt;sup&gt;2&lt;/sup&gt; (words; auditory/visual)</td>
<td>45/50*</td>
<td>24/25</td>
<td>22/25</td>
<td>24/25</td>
<td>20/25</td>
<td>&gt;5th %ile</td>
<td></td>
</tr>
<tr>
<td>Concrete synonyms test&lt;sup&gt;3&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>24/25</td>
<td>20/25</td>
<td>&gt;2&lt;sup&gt;nd&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Naming (verbal description)</td>
<td>22/30</td>
<td>19/20</td>
<td>18/20</td>
<td>19/20</td>
<td>19/20</td>
<td>Normal range: ~20–22</td>
<td></td>
</tr>
<tr>
<td>Cognitive estimates&lt;sup&gt;4&lt;/sup&gt; (error score)</td>
<td>–</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>10</td>
<td>Visits 3 and 4: &lt;5th %ile</td>
<td></td>
</tr>
<tr>
<td>A Cancellation&lt;sup&gt;5&lt;/sup&gt; Completion time</td>
<td>–</td>
<td>46s</td>
<td>82s</td>
<td>60s</td>
<td>105s</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Letters identified</td>
<td>14/19</td>
<td>14/19</td>
<td>10/19</td>
<td>7/19</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading (CORVIST&lt;sup&gt;9&lt;/sup&gt;)</td>
<td>16/16</td>
<td>16/16</td>
<td>15/16</td>
<td>14/16</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculation (Extended GDA&lt;sup&gt;6&lt;/sup&gt; – addition items only)</td>
<td>14/26</td>
<td>9/26</td>
<td>9/26</td>
<td>9/26</td>
<td>Normal range: 5–9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spelling (GDS&lt;sup&gt;7&lt;/sup&gt; – Set B, 1&lt;sup&gt;st&lt;/sup&gt; 20 items)</td>
<td>16/20</td>
<td>15/20</td>
<td>12/15</td>
<td>11/15</td>
<td>Visits 3 and 4: &lt;5th %ile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gesture production test&lt;sup&gt;8&lt;/sup&gt;</td>
<td>–</td>
<td>15/15</td>
<td>6/10</td>
<td>–</td>
<td>Normal range: 5–9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit span (maximum forwards)</td>
<td>7*</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early visual processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Figure-ground discrimination (VOSP&lt;sup&gt;10&lt;/sup&gt;)</td>
<td>19/20</td>
<td>15/20</td>
<td>16/20</td>
<td>16/20</td>
<td>Visits 1–4: &lt;2&lt;sup&gt;nd&lt;/sup&gt; %ile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape discrimination&lt;sup&gt;11&lt;/sup&gt; (Oblong edge ratio 1:1.20)</td>
<td>20/20</td>
<td>18/20</td>
<td>16/20</td>
<td>15/20</td>
<td>Healthy controls: no errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hue discrimination (CORVIST)</td>
<td>4/4</td>
<td>3/4</td>
<td>3/4</td>
<td>1/4</td>
<td>Normal range: ~3–4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual crowding</td>
<td>–</td>
<td>–</td>
<td>4/10</td>
<td>7/10</td>
<td>Impaired</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visuoperceptual processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object decision (VOSP)</td>
<td>10/20</td>
<td>8/20</td>
<td>4/20</td>
<td>4/20*</td>
<td>UT</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Fragmented letters (VOSP)</td>
<td>11/20</td>
<td>–</td>
<td>–</td>
<td>0/20</td>
<td>UT</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Unusual and usual views&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Unusual</td>
<td>2/20</td>
<td>–</td>
<td>2/20</td>
<td>–</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Unusual</td>
<td>2/20</td>
<td>–</td>
<td>–</td>
<td>6/20</td>
<td>–</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Usual</td>
<td>10/20</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Visuospatial processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number location (VOSP)</td>
<td>5/10</td>
<td>3/10</td>
<td>1/10</td>
<td>0/10</td>
<td>UT</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>Dot Counting (VOSP)</td>
<td>3/10</td>
<td>7/10</td>
<td>2/10</td>
<td>1/10</td>
<td>1/10</td>
<td>&lt;1&lt;sup&gt;st&lt;/sup&gt; %ile</td>
<td></td>
</tr>
<tr>
<td>MOT Screening Test (CANTAB)</td>
<td>Mean RT (ms)</td>
<td>1631</td>
<td>1375</td>
<td>2025</td>
<td>Age-matched female controls (N = 15): 909ms (sd 296ms)&lt;sup&gt;14&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed touches</td>
<td>–</td>
<td>–</td>
<td>2</td>
<td>5</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ABNORMAL VISUAL PHENOMENA IN PCA

ABNORMAL VISUAL PHENOMENA IN PCA

subsequently co-registered to baseline using an affine (12 dof) (3 translations, 3 rotations, 3 scalings and 3 shears) brain–brain registration, to correct for any voxel-size changes due to slight variation in the scanner magnetic field. This registration also used a differential bias correction to correct for differences in intensity inhomogeneity between serial scans (Lewis & Fox, 2004).

Fluid registration was used to visualize areas of contraction and expansion across the whole brain for each time step (Christensen, Rabbitt, & Miller, 1996). The fluid algorithm used here was largely as described by Freeborough and Fox (1998). A medial sagittal view of CRO’s right hemisphere from the baseline scan at visit 1 as well as the fluid-registered scans at visits 2–4 are shown in Figure 1. As indicated by the colour-coded voxel-compression map, CRO showed progressive atrophic changes with a marked anterior-posterior gradient over this 3-year interval. The pattern of atrophy was characterised by ventricular enlargement, as well as marked contraction in regions of the parietal and occipital lobes, with noticeable sparing of the cerebellum across all time steps. By the time of CRO’s last visit there was widespread atrophy across the whole brain, however, the anterior-posterior gradient was still clearly visible.

ABNORMAL COLOUR AFTER-IMAGES

As noted in the clinical description, one of CRO’s presenting features was of perceiving coloured patches at the edge of her visual field. During subsequent visits, she also described ‘washes of colour’ across the visual environment and particular difficulty when moving from areas of bright light to areas of lower light (e.g., going from the garden into the house on a bright day), with her vision taking a long time to adapt to the new levels of ambient light. She also reported seeing cream-coloured stripes when clearing her white bed linen. This observation was reminiscent of a previously reported individual with PCA (Patient VL; Chan et al., 2001) who had reported perceiving her hands to be green for 30–60 s after laying out her red bed linen. Thus we decided to assess CRO’s colour perception and then to administer a subset of the tasks used to investigate the abnormal duration of VL’s colour after-images.

Figure 1. Registered serial MR images showing a medial sagittal view of CRO’s right hemisphere at Visits 1–4 (ages 58–61 years old). Repeat scans were fluid-registered to the baseline image and colour-coded voxel-compression maps were produced. The scale shows the percentage volume change per voxel (%−20 to 20%) with green and blue representing contraction and yellow and red representing expansion.
Experiment 1a: Hue discrimination

Methods

A background test of hue discrimination was administered to assess colour perception skills. The stimuli were pairs of matte colour chips presented adjacent to one another mounted on white A6 cards. The colours were selected from the red, green and purple hue ranges of the Munsell colour system, and were of fixed value and chroma (6/6). Task difficulty was varied by altering the distance between hue pairs on the Munsell hue scale. There were three levels of difficulty: Easy (8 degrees of separation), Intermediate (4 degrees of separation) and Difficult (2 degrees of separation). At each level of difficulty, 8 pairs of colour chips were shown in the red, green and purple ranges of the spectrum. In each set of 8 pairs, half the pairs were the same hue and half the pairs were different hues. For all stimuli, CRO was requested to state whether the colour chips were the same hue or different hues.

Results

CRO made no errors in the easy condition (8/8 in each colour range), occasional errors in the intermediate condition (Red = 8/8; Green = 6/8; Purple = 6/8) and frequent errors in the difficult condition (Red = 6/8; Green = 5/8; Purple = 5/8). This corresponds to weak but not grossly impaired colour perception, as healthy controls tend to make occasional errors only on the hard condition.

Experiment 1b: Colour and duration of after-images

Methods

Under white room lighting conditions, the patient was asked to fixate binocularly on red, blue, green or yellow coloured A5 sized cards of equal luminance placed on a neutral light grey background. The colour cards were presented for durations of 5, 10 or 15 s. After presentation, the test card was removed and the patient was asked to fixate on the grey background and to describe the duration and colour of any after-images. Each colour was presented only once at each presentation duration. CRO reported the colour and duration of any after-images perceived immediately after the presentation of the colour stimuli.

Results

The perceived duration of each abnormal colour is shown in Figure 2, together with the previously collected data from VL and 3 age-matched healthy control participants reported in Chan et al. (2001). CRO’s after-images were in the majority of cases notably longer than in controls, and her colour descriptions tended to be the complimentary colour of the previously presented colour stimulus. She reported seeing ‘pink’ following all green stimuli, ‘purple’ or ‘lilac’ after all yellow stimuli, ‘turquoise’ after the 15-s red stimulus, and ‘yellow’ or ‘sunrise’ after the 15- and 10-s blue stimuli. The only exceptions were red 5 s (‘nothing’), red 10 s (‘grey’) and blue 5 s (‘pink at the bottom’).

Comment

CRO’s descriptions of abnormal colour perceptions were very similar to those of patient VL, and when tested using the same colour patch stimuli, CRO also showed comparable increases in colour afterimage duration compared with healthy control subjects. As with VL, these after-images were observed in the context of mildly impaired colour perception. In the Discussion, we evaluate whether these prolonged afterimages reflect a relative sparing of inhibitory interneurons in V1.

Figure 2. Duration of CRO perceived colour after-images. Also shown are the mean after-image durations reported by patient VL and 3 healthy age-matched control participants based on three presentations of each colour stimulus (from Chan et al., 2001).
PERCEIVED MOTION OF STATIC STIMULI

During the standard assessment of CRO’s visuospatial processing skills, she was administered several subtests from the VOSP (Warrington & James, 1991). Of particular note was her comment following completion of the Dot Counting subtest (which as the name suggests involves counting 5–9 black dots printed on a white background), that the task was rather unfair because the dots kept moving around on the page. This tallied with her conscious experience of other visual arrays containing small items (e.g., words on a page) in which the location of items appeared to alter. Her description particularly of letters moving within a word was reminiscent of some forms of developmental dyslexia, in which reading difficulties are associated with unsteady eye fixations and attributed to impairments of the visual magnocellular system (Ray, Fowler, & Stein, 2005; Stein, 2003; Wilkins, 2003). In the current section, we report attempts to modify this perceived motion of static stimuli using colour filters (Experiment 2a), and an analysis of the relationship between eye movement and perceived motion (Experiment 2b).

Experiment 2a: Dot Counting and Number Location with and without a colour tint

One technique used to counter unsteady fixations and poor vergence control in developmental dyslexics is to read through colour filters. Although magnocellular cells are not involved in colour perception, M-ganglion cells receive inhibitory input from long- (L; red), medium- (M; green) and short- (S; blue) wavelength sensitive cones (Roorda & Williams, 1999). Different colour filters may act to reduce components of this inhibitory input (e.g., yellow filters reducing S-cone inhibitory input), thus increasing magnocellular function and improving dependent functions such as contrast and motion sensitivity. Here we piloted the use of a similar colour tint as a technique for reducing CRO’s sense of perceived motion of static stimuli.

Methods

CRO was administered two spatial tasks (Dot Counting and Number Location) with and without a colour overlay (transparent green cellophane) on two occasions (Trials 1 and 2).

i. Dot Counting: The stimuli were arrays (N = 28) of 3–9 dots in a randomised spatial arrangement. Trial 2 arrays had the same spatial arrangement as Trial 1 but were reproduced at 50% scale.

ii. Number Location: Taken from the VOSP Number Location task (Warrington & James, 1991), the stimuli consisted of two identically sized squares printed one above the other; the top square contained randomly positioned Arabic numerals and the bottom square a single black dot. CRO was requested to identify which number in the top square occupied the same spatial position within its square as the dot in the bottom square. For both Trial 1 (N = 12) and Trial 2 (N = 22), the presence of a colour overlay was varied in an ABBA design.

Results

i. Dot Counting: On Trial 1, CRO was significantly more accurate counting dots with the green tint than without [Tint = 22/28, No tint = 13/28; \( \chi^2(1) = 6.17, p = .013 \)]. However, this significant effect did not replicate on Trial 2 where overall response accuracy was much lower and there was only a small advantage for the green tint condition [Tint = 9/28, No tint = 5/28; \( \chi^2(1) = 1.52, p = .22 \)].

ii. Number Location: On Trial 1, CRO responded more accurately with the tint than without, an advantage which approached formal levels of statistical significance [Tint = 10/12, No tint = 5/12; \( \chi^2(1) = 3.00, p = .083 \)]. However, this effect did not replicate as on Trial 2 CRO showed no difference between the two conditions (Tint = 12/22, No tint = 12/22).

Experiment 2b: Eye movements associated with perceived motion of static stimuli

Further investigations of CRO’s perceived motion of static stimuli effect were conducted in December 2009. Eye movements are of importance in understanding CRO’s perception of motion of static stimuli as eye position signals play a critical role in normal space constancy. The healthy brain achieves a steady perception of the world despite changes in the retinal position of visual stimuli by remapping space into co-ordinates based on upcoming rather than current fixation point. In Experiment 2b, an eye-tracking system was used to
monitor the stability of CRO’s fixation when observing single and multiple item arrays.

Methods

CRO was presented with a single 0.8° diameter black dot on a light grey background under ambient lighting and was asked to fixate and to report whether the dot appeared to be static or moving. CRO was subsequently presented with 8 arrays of 1–4 dots, again with diameter 0.8° and with a minimum spacing of 1.6° and a maximum eccentricity of 6°, and was requested to count how many dots were on the screen. All stimuli were presented at the centre of the display, with onset triggered by CRO fixating upon a central fixation cross which preceded each stimulus. Gaze position was monitored online at 1000 Hz, using a frame-mounted infrared eye tracker (EyeLink 1000, SR Research Ltd, Canada). The patient’s fixation was unstable when we attempted to record eye position, making it extremely difficult to obtain good calibration of the eye tracking device. Consequently only a relatively small amount of data was collected. The patient completed two long trials, of durations: 30 and 20 s, respectively, in the stable fixation task. Calibration was acceptable in Trial 1, but less optimal in Trial 2.

Results

CRO’s horizontal and vertical eye positions over the entire duration of Trial 1 of the single dot fixation task are shown in Figure 3a. A complementary heat map showing the density of gaze positions at each point on the display screen is shown in Figure 3b. There was minimal eye movement with no saccades during the period when CRO reported stable perception of the dot. However, numerous shifts in eye position were noted during the period when the patient reported dot movement. In order to calculate the proportion of time when fixation was steady or unstable, the following criteria were used: (i) Gaze within 5° from the centre (i.e., looking at the target); (ii) Gaze position did not change more than 0.1° in the last 200 ms. Using these criteria to define ‘steady fixation’, gaze was stable on only 20.1% (Trial 1) or 11.8% (Trial 2) of the time. On the arrays of 1–4 dots, CRO was able to count the items correctly on only 5/8 occasions. The single item display was the only ‘array’ which CRO enumerated correctly on both the occasions it was presented. Unfortunately, due to inadequate calibration, reliable data was acquired only from trial 5 (a 4-item array; see Figure 4). The heat map of gaze position density indicates that on this trial, the correct response may have been provided somewhat by a chance summation, with two dots fixated twice and two dots never fixated.

Comment

There was some limited evidence that, in some instances, an intervention which may have increased aspects of magnocellular function improved the accuracy of CRO’s performance on two tests of visuospatial processing, both of which involve multiple target stimuli spatially dispersed within presentation arrays. This poor performance may in part by influenced by impaired numerosity judgements. However, measurement of eye movements indicated some form of relationship between CRO’s perception of motion among static items and the occurrence of eye movements. Indeed, fixation instability had a particularly pronounced cost when CRO was attempting tasks requiring more than a single point of fixation. However, the causal relationship between her perception of motion and eye movements remains to be established. The perception of motion among static items could be caused directly by involuntary eye movements. Alternatively, rather than being involuntary, the eye movements detected in this experiment could reflect the attempt to fixate an incorrectly remapped stimulus, therefore producing a vicious circle of voluntary saccades. This saccadic cycle could be initiated by a spurious, small amplitude eye movement that might be voluntary or involuntary.

Inverse Size Effects

From the time of her referral, CRO reported increasing difficulties with reading, which initially were characterised by losing her place on the page and having difficulty moving from the end of one line of text to the beginning of the next. Such spatial dyslexic deficits are reported commonly by individuals with PCA. However, in 2005, CRO made two comments which suggested that her problems with reading sometimes related to the size of the text. First, she mentioned that she had particular difficulty reading the headlines in newspapers. Second, she also described how, in an effort to counteract her reading problems, she had gone to her local public library to borrow large
print books, designed for the ‘visually impaired’. Ironically, she found these texts infinitely more difficult to read than normal size print. These observations led us to evaluate the effect of size upon her processing of letters, numbers, words, and a selection of stimuli designed for testing aspects of early visual processing.

**Experiment 3a: Letter size**

**Methods**

The stimuli were 24 uppercase letters (all alphabetic items except I and O) in Arial font. All stimuli were presented at 3 different font sizes: large (1000; letter height 20.4\(^\circ\)), medium (250; 5.0\(^\circ\)) and small (80; 1.6\(^\circ\)). The stimuli were viewed on a Dell Inspiron 510m laptop computer from a viewing distance of 50 cm for 150 ms with no fixation or mask using Superlab Pro software. The large, medium and small stimuli were administered in blocks of 8 items using a Latin square design. CRO was asked to name each letter.

**Results**

The percentage correct responses are shown in Figure 5. A Cochran $Q$-test of differences between

![Figure 3](337x288)
conditions demonstrated a significant trend toward an inverse size effect, with response accuracy significantly higher with smaller stimuli ($Q = 43.5, p < .001, \text{df} = 2$).

**Experiment 3b: Number size**

**Methods**

A comparable test of the effect of font size upon number identification was conducted, using 9 single Arabic numerals (1–9) in Arial font. All stimuli were presented twice at 3 different font sizes: large (500; 10.3°), medium (250; 5.0°) and small (80; 1.6°). The stimuli were all viewed for 150 ms using the same apparatus and design as in the letter experiment.

**Results**

The percentage numbers named correctly are shown in Figure 5. Consistent with her performance in Experiment 3a, CRO named smaller items
more accurately than larger items, an inverse size effect which was shown to be statistically significant \( (Q = 25.1, p < .001, \text{df} = 2) \).

**Experiment 3c: Word size**

**Methods**

The effect of font size upon word reading accuracy was assessed using 16 four-letter words and 16 eight-letter words shown in uppercase Arial font. The 4- and 8-letter words were matched for CELEX frequency but the 8-letter words naturally had fewer orthographic neighbours than the 4-letter words (4-letter words: mean CELEX = 168.4, SD CELEX = 195.3; Mean \( N = 8.94 \); 8-letter words: mean CELEX = 153.8, SD = 96.3; Mean \( N = 0.38 \)). All words were presented at 2 different font sizes: large (150; letter height 3.0°) and small (60; 1.2°). The words were presented for 150 ms in an overall ABBA design using the same apparatus as in the letter and number experiments.

**Results**

The percentage correct responses for large and small font size words are shown in Figure 5. A more detailed breakdown of the number of correct responses is shown in Table 2. CRO read small font words significantly more accurately than large font words (Sign test: \( N = 15, x = 0, p < .01 \)). She was also significantly more accurate reading 8- than 4-letter words, \( \chi^2(1) = 4.02, p = .045 \). The errors made by CRO were either visual errors (\( N = 13 \); e.g., date → skate, gray → gravy), omissions (\( N = 11 \)) or miscellaneous (\( N = 3 \); e.g., trouble → village).

**Experiment 3d: Eye positions associated with inverse size effects**

Further investigations of CRO’s better reading of small than large letters were conducted in December 2009, using an eye-tracking system to assess the fixation pattern associated with observing two example words from Experiment 3c presented at different font sizes.

**Methods**

The word ‘NATURAL’ was presented twice, at different font sizes: 12 (letter height 1°) and 60 (2.12°). The word ‘KING’ was also presented twice, at font sizes 12 (1°) and 150 (5.29°). Both words were presented at the centre of the screen, triggered by CRO’s fixation upon a preceding central fixation cross. CRO was requested to name each item. Owing to calibration difficulties, only a limited number of stimuli were presented; the word stimuli ‘NATURAL’ and ‘KING’ were administered interspersed with 9 other letter, number and word stimuli, the data for which are not presented here.

**Results**

CRO read both target words correctly in the font 12 condition, but was unable to identify the word or even any constituent letters in the larger font conditions (e.g., NATURAL: ‘a lot of letters, I can’t make them out’). The density of eye positions at each location on the screen when attempting to read the word NATURAL at both small and large font sizes are shown in Figure 6. These example figures demonstrate a relatively stable fixation point near the initial letter for the successfully read small font item, but a much more spatially distributed array of shorter duration fixations for the larger font presentation.

**Comment**

CRO’s clinical descriptions of having greater difficulty reading large sized print were confirmed empirically. She was able to identify single letters, Arabic numerals and single words significantly more accurately when printed in smaller fonts. CRO’s inability to perceive larger items was associated with multiple fixations in and around the stimulus area. These observations suggest a reduction in receptive field size (and consequently a reduction in the field of effective vision), with eye movements partly reflecting an unsuccessful search for a fixation point where sufficient perceptual information can be obtained to permit accurate identification of target features.

It was also noted that she read long words more accurately than short words, a fact which is likely

<table>
<thead>
<tr>
<th></th>
<th>Large (font size 150)</th>
<th>Small (font size 60)</th>
<th>TOTAL</th>
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<tr>
<td>4-letter words</td>
<td>2/16</td>
<td>11/16</td>
<td>13/32</td>
</tr>
<tr>
<td>8-letter words</td>
<td>9/16</td>
<td>15/16</td>
<td>21/32</td>
</tr>
<tr>
<td>TOTAL</td>
<td>11/32</td>
<td>26/32</td>
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</tbody>
</table>
to reflect that multiple factors other than the physical size (length) of word stimuli affect the likelihood of accurate identification. For example, the 4-letter words had far higher orthographic neighbourhood ratings (the number of alternative words which can be formed by changing only one letter in the target), meaning there was a much larger neighbourhood of competitor words with similar orthography which might be mis-selected to produce visual reading errors.

**ROOM TILT ILLUSION**

One recent experience which CRO reported at the beginning of 2009 was of a transient episode of room tilt illusion. Transcribed from an audio recording [with investigator questions in brackets], CRO described this unusual event as follows:

It was a couple of, two or three or four weeks ago, and it was very odd, and I was in the kitchen or something and I think probably I’d come downstairs or something. Anyway, when I got downstairs the whole of the room was upside down, which was actually very scary but I got over that when I realised it was OK if you know what I mean. But it was completely, the bottom was on the top and the top was on the bottom. Do you see what I mean? It was most peculiar. [Had that ever happened to you before?] No. It was quite scary actually, and it was really quite difficult to orientate myself because I wasn’t quite sure whether I really was upside down, you know, silly things can happen can’t they, or whether it was just the image in my brain or whatever else had turned me inside out basically. [And what did you do when that happened to you?] Erm, sat down, and well I did a bit of blinking and things like that as you would, and nothing really happened and then it just sort

![Figure 6. Example heat maps showing density of gaze positions at each location on the screen for the same word presented at (A) small font size (and consequently correctly read) and (B) large font size (and consequently incorrectly read).](image-url)
Of, I suppose I must have stood up or done something different or something, and it just was OK. . . . [And how long do you think it lasted for?] Probably three or four minutes, maybe a bit longer, but not much longer than that. [And when it stopped happening, did it just flip back suddenly?] Yes, it flipped back. I wasn’t sort of half and half.

Of relevance to the report of room tilt illusion was CRO’s history of benign paroxysmal positional vertigo (BPPV). However, CRO was very clear that this episode was quite distinct from any previous experiences of vertigo, which occur following rapid changes in posture. ‘If I get up too suddenly or down too suddenly my head can spin, but it’s not that, this was entirely different’. Nonetheless, to consider the basis for CRO’s room tilt illusion further, a detailed neuro-otological assessment was conducted.

Neuro-otological assessment

Bedside eye movement examination was carried out using a large 30-cm diameter black circle as a target fixation. There was a full range of eye movements in vertical and horizontal planes, with no spontaneous or gaze-evoked nystagmus. Pursuit movements were normal horizontally, with occasional saccadic intrusions. Vertical pursuit was broken but within the normal age range. Saccadic eye movements appeared normal, although a precise assessment was limited due to the patient’s difficulty with target fixation. The vestibulo-ocular reflex (VOR) – assessed using the head impulse test (ref: Halmagyi GM, Curthoys IS, Arch Neurol 1988) – was intact bilaterally, implying normal vestibular nerve function. There was no skew deviation of the eyes and no head tilt. Given the history suggestive of benign positional vertigo, a positioning (Hallpike) manoeuvre was performed. This elicited nystagmus consistent with right sided posterior canal BPPV. Importantly, the Hallpike manoeuvre did not trigger a room tilt illusion.

Clinical investigations

Electronystagmography (ENG) was limited due to the patient’s difficulty with small target fixation and roaming eye movements. Whilst seated on a motorised chair, the patient was asked to fixate on a computer-controlled coloured target 60 cm away. The patient’s head was secured using a padded chin rest, and eye movements were recorded with surface electrodes placed around the eyes. To test saccadic eye movements, the target was first moved 30° to the right, then 30° to the left, and the patient was asked to follow this with her eyes. Pursuit movements were tested by moving the target horizontally (sinusoidally) from left to right, and the patient was again asked to follow the movement with her eyes. The chair was kept stationary during these conditions. To test peripheral vestibular function, the patient was rotated at 90°/s in the dark, first to the right, then to the left and eye movements were again recorded. Vestibular responses to chair rotation were symmetrical and of normal duration suggesting intact vestibular function. A bithermal caloric showed no evidence of a canal paresis and no asymmetry of vestibular function. The patient also underwent assessment of the subjective visual vertical (SVV). Whilst seated 60 cm away from a laser target (rod-shaped) projected onto the wall, in an otherwise dark room, she was asked to align the laser rod with the perceived gravitational vertical. While the patient’s eyes were shut, the experimenter offset the rod (between 30° and 60° to either side). Six trials were recorded. There was a mean leftward offset of 2.5° which is within the normal range.

Comment

This episode of apparent room tilt illusion was clearly and coherently described, qualitatively different to previous episodes of BPPV, and occurred in the context of severe visual dysfunction. To summarise the neuro-otological examination, a positioning (Hallpike) manoeuvre revealed nystagmus consistent with posterior canal BPPV but this manoeuvre did not trigger a room tilt illusion, and clinical laboratory investigations showed normal and symmetrical vestibular function. We are unaware of any previous reports of room tilt illusion linked to cortical degenerative disease. As the room tilt illusion has occurred only once to date and not in the presence of the investigator, direct examination and questioning of the participant whilst experiencing the phenomenon has of course not been possible. In the Discussion, consideration is given to whether this occurrence of room tilt illusion reflects a discrepancy between visual, vestibular and proprioceptive spatial maps of verticality.

DISCUSSION

Posterior cortical atrophy (PCA), the degenerative condition most commonly considered to be the
‘visual’ or ‘biparietal’ variant of Alzheimer’s disease, is attracting increased clinical recognition and research interest. In this study, we describe a single individual with PCA who reported a number of abnormal visual phenomena, and our preliminary attempts to quantify and examine each of these symptoms. In our clinical experience, some of these phenomena are experienced commonly by other PCA patients (perceived motion of static stimuli, and colour after image effects) whilst others have not been reported previously in this clinical population (room tilt illusion). Here we summarise briefly the characteristics of each of these phenomena and consider potential aetiologies for these symptoms.

Prolonged colour after-images

The first unusual visual phenomenon examined was that of prolonged colour after-images, which are reported commonly in the context of PCA. Sometimes these colour abnormalities take the form of non-specific patches of colour in the visual periphery (as with CRO in the earliest symptomatic phases of the disease). In other situations, and possibly later in the disease course, these abnormal colours are experienced more centrally in the visual field, and can often be understood as being complementary in colour to other prominent stimuli in the current or recent visual environment. For example, another patient with PCA (Patient 2; Crutch & Warrington, 2007) reported having to ask her partner why the England football team were playing in a pink strip; this perception of pink is likely to have reflected a concurrent and persistent pink/red afterimage overlaying the neutral white England shirts owing to the background green stimulus of the football pitch grass.

After-images of abnormal duration have previously been quantified in a patient with PCA (VL; Chan et al., 2001). Tested using the same stimuli as VL, CRO also showed considerably longer duration of colour afterimages following exposure to various colour stimuli. Although the durations of after images was only measured on one occasion for each colour at each exposure duration (as opposed to averaging across three presentations under each condition as in Chan et al., 2001), CRO gave clear self-reports and the colour of each afterimage tended to be a complementary colour of the stimulus.

Functional neuroimaging studies have reported that colour afterimages in healthy individuals are associated with activity in V8 just anterior to V4 (Hadjikhani, Liu, Dale, Cavanagh, & Tootell, 1998). As Chan et al. (2001) argued one possible mechanism for the abnormal elongation of these after images is excessive rebound inhibition of previously excited wavelength selective neurons in V1. This may occur as a consequence of the relative sparing of inhibitory interneurons in V1 in the context of the degeneration of excitatory neurons that occurs in Alzheimer’s disease. It is an open question whether only some or all brain regions within the normal colour processing system remain activated for an abnormal period following the presentation of colour stimuli in such PCA patients.

Perceived motion of static stimuli

The perceived motion described by CRO when viewing an array of static stimuli in the absence of any moving stimuli can be distinguished from a number of normally occurring motion phenomena and after effects such as ‘induced motion’, the impression that a static stimulus moves relative to the head in the context of other stimuli which actually are moving (e.g., Nefs & Harris, 2008). One possibility is that this sense that static stimuli were moving occurred as a result of disordered eye fixations and movements.

A variety of visual, proprioceptive and vestibular cues act to determine the amplitude and direction of eye movements required to maintain stability of the image on the fovea (i.e., space constancy e.g., Hess & Angelaki, 2003; Wurtz, 2008). Indeed, eye movements play an important role in normal space constancy, with information about the intention to make a saccadic eye movement used to compensate for the movement by remapping spatial representations upon the co-ordinates of the intended rather than current eye position (e.g., Duhamel, Colby, & Goldberg, 1992; Lappe, Awater, & Krekelberg, 2000). In this way, the perceived motion of static stimuli could reflect problems with one or more of these constituent processes (e.g., visual reafferance [the visual motion signal generated by eye movements], eye muscle proprioception, corollary discharge of eye movement commands). For example, gaze stability could be affected because inaccurate vestibular signals are stimulating eye movements away from the current fixation point, or because of a deficit in eye movement planning and control in the context of accurate vestibular signals. On either account, it
would be predicted that the perceived motion of static stimuli should not be observed when fixation is held in one location in the absence of head or eye movements.

Eye-tracking data in the current study confirm this prediction: when looking at a single dot, CRO only reported the position of the dot as static when there were no concurrent horizontal or vertical changes in eye position. The instability of fixation in CRO is also consistent with FDG-PET evidence showing reduced glucose metabolism in patients with PCA not only in posterior brain regions but also in the frontal eye fields bilaterally (Nestor, Caine, Fryer, Clarke, & Hodges, 2003). It was suggested that this hypometabolism might be secondary to a loss of input from occipital and parietal regions and might account for the ocular apraxia seen in some patients with PCA.

The attempts described in the current paper to ameliorate the perceived motion of static stimuli using a coloured filter were only provisional in nature, and were based on the notion of magnocellular-upregulation (e.g., Stein, 2003). However, CRO’s improved spatial perception under colour conditions in two tasks represents some evidence that should motivate further detailed studies of the effects of colour filters upon gaze stability and perceived motion of static stimuli in PCA patients.

**Better reading of small than large letters**

Turning to the reading of small and large letters, CRO demonstrated a reliable and significant advantage for identifying smaller letters, Arabic numerals and words. These experimental findings concur with CRO’s reported difficulties with reading headlines and large print ‘easy reading’ books. The data are also compatible with the anecdotal case of an individual with PCA who described to his clinician sitting in a train carriage and being unable to read the headlines in his own newspaper but being able to perceive the headlines in a copy of the same newspaper being read by another passenger seated further down the carriage (Fox, personal communication).

The tendency for patients with progressive visual disturbance to have greater difficulty recognising large as compared with small pictures and other stimuli has been described on several occasions (e.g., Pick, 1908 cited in Bender & Feldman, 1972; Coslett et al., 1995; Saffran et al., 1990; Stark et al., 1997). For example, Stark et al. (1997) reported patient NJ whose clinical picture was compatible with PCA and who was more accurate in identifying small than large pictures, words and single letters. Most of these reports have interpreted reverse size effects or better reading of small than large letters in terms of a deficit in selective attention or slightly more specifically a restricted ‘spotlight’ of attention such that visual features cannot be integrated over as large an area as in healthy controls (e.g., Stark et al., 1997; cf. Treisman & Gelade, 1980).

A related formulation is that PCA patients show a reduction in their ‘effective visual field’, consistent with data from healthy individuals and patients with right temporo-parietal damage that attention dynamically modulates the detection of stimuli in the periphery (Russell, Malhotra, & Husain, 2004). In addition, better reading of small than large letters may be exacerbated by problems with directing and detecting eye movements (see the explanation of perceived motion of static stimuli phenomena above). Larger stimuli may require or stimulate shifts in fixation to appreciate key features, with disordered eye movements and compromised oculomotor feedback leading to the impaired integration of featural information across the visual field.

**Room tilt illusion**

We finish by considering the most striking and unusual visual experience described by CRO, namely room tilt illusion. The perception of verticality relies upon the integration of visual, vestibular and proprioceptive afferent stimuli, with multimodal cells in posterior parietal cortex heavily implicated in the integration process (e.g., Andersen, Essick, & Siegel, 1985; Brandt, 1997; Sakata & Kusunoki, 1992). A discrepancy between these three modalities can create an erroneous illusion of movement or altered spatial position (Malis & Guyot, 2003).

The complete 180° inversion of the visual world was first reported by Bishop in 1805 and attributed to hysteria (Bishop, 1805). Room tilt illusion (also sometimes referred to as reversal of vision metamorphopsia) involves a transient 180° or 90° rotation in the visual field in the coronal plane (Hernandez et al., 2006), although sagittal rotations have been reported (Tanaka, Takeda, & Hamanaka, 1996). This phenomenon has been reported following damage to the brain stem, cerebellum or other
cortical lesions (River, Ben Hur, & Steiner, 1998; Steiner, Shahin, & Melamed, 1987) but most commonly after vertebro-basilar ischaemia. A review of 18,000 patients presenting to a neuro-otology unit found 23 cases of room tilt illusion following peripheral vestibular disorders. In three cases, the phenomenon was associated with BPPV, and occurred during the diagnostic Hallpike manoeuvre in all cases (Malis & Guyot, 2003). Hayashi, Yamaguchi, Katsumata, and Mimura (2009) reported room tilt illusion of 90° in a patient with Parkinson’s disease associated with other visual hallucinations. They hypothesised that this resulted from hypoperfusion in the posterior region of the right intraparietal sulcus causing a mismatch between visual and vestibular inputs.

However, we are unaware of any previous reports of room tilt illusion in individuals with a cortical degenerative disease. We would suggest that in the current case, this phenomenon is likely to reflect a discrepancy between visual, vestibular and proprioceptive spatial maps of verticality. Defective visual processing is strongly implicated as this episode was observed in the context of posterior cortical atrophy, was never experienced prior to the PCA diagnosis, and was experienced subjectively as a completely different phenomenon to previous episodes of BPPV. In addition, despite demonstrating active posterior canal-BPPV, the clinical examination and vestibular investigations, showed normal peripheral vestibular function, and excluded peripheral and central otolithic dysfunction. More importantly, positioning manoeuvres did not trigger the room tilt illusion in our patient. Indeed, if this illusion were caused by BPPV, one would have expected the room tilt to have occurred more than once, given how active the positional vertigo was when tested with provocation manoeuvres (Hallpike). It is therefore more likely that the phenomenon occurred as a result of impaired visuo-vestibular processing at the cortical level, where visual and vestibular inputs were perhaps transiently aberrantly encoded. CRO also showed no evidence of vertebro-basilar infarction. The room tilt illusion may have occurred only transiently because subsequent additional visual analysis of the scene improved the visual input signal which was then more successfully and adaptively integrated with online vestibular and proprioceptive information. The reason why the illusion has occurred only once remain unclear, but clinical experience suggests an number of PCA patients experience more persistent and regular disruptions of visuo-vestibular processing. As this symptom has occurred only once in this patient, it is too early to label room tilt illusion as a common feature of PCA. However, this finding, together with clinical complaints of balance problems, giddiness and unsteadiness from other PCA patients seen in our clinical service, suggest vestibular function should be examined in detail in this patient population.

In conclusion, all of the deficits of visual cognition which individuals with PCA describe can be accurately characterised as ‘negative’ in the sense that they contribute to a profound and progressive functional impairment which reduces or prevents performance and enjoyment of numerous pastimes and daily activities. However, some symptoms could be construed as ‘positive cognitive phenomena’ in that the individual does not merely fail to perceive a stimulus property which is present, but has a ‘positive’ perception of stimulus attributes which are not present. One certainty is that the abnormal visual phenomena reported in the current paper constitute but a few of the unusual and poorly understood symptoms experienced by individuals with PCA. It is anticipated that further detailed investigation of the basis of such phenomena, and systematic evaluation of their prevalence in a prospective cohort of PCA patients, may contribute to our elucidation of the disease process in PCA and the development of aids and strategies to reduce the real-life cost of visual dysfunction for these individuals.

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