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Colour discrimination thresholds in Parkinson's disease: results obtained with a rapid computer-controlled colour vision test

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Abstract

A dysfunction of dopaminergic retinal neurons is thought to occur in Parkinson's disease, manifesting itself in impaired performance on various visual discrimination tasks. We have investigated whether differences in colour discrimination could readily be detected between a normal group and a Parkinsonian group, using a computer-controlled test of colour vision. Although some individual Parkinsonian patients showed an abnormal elevation of colour discrimination thresholds, there was no significant difference between the normal group and the Parkinsonian group.

Keywords: Colour vision; Colour discrimination; Parkinson's disease

1. Introduction

1.1. Disturbance to visual function in Parkinson's disease

Disturbances to visual function have repeatedly been reported in patients with Parkinson's disease (PD), including longer latencies for VEPs [1], reduced sensitivity to flicker [2], and reduced contrast sensitivity [2,3], particularly for spatial frequencies above 4.8 c/d. It has also been reported that colour vision is impaired in PD [4,5] and recent work has suggested that these disturbances to colour vision affect predominantly the short-wave (S) cone pathway [6,7].

1.2. The retinal dopamine hypothesis

It has been argued that these visual deficits arise at least in part from dopamine deficiency in the retina [8]. The chemical MPTP (1-methyl, 4-phenyl, 1-2-5-6-tetrahydropyridine) produces a parkinsonian syndrome in monkeys. Following MPTP treatment, the latency and amplitude of VEPs and pattern ERGs to grating stimuli are altered in monkeys, but recover on administration of L-DOPA with carbidopa, suggesting that the abnormalities arise from dopamine deficiency. That the deficit is at least partly retinal is suggested by the effect of intravitreal injection of the dopaminergic neurotoxin 6-hydroxydopamine (6-OHDA), which causes the same VEP and pattern ERG abnormalities as systemic MPTP [8].

There are thought to be at least two classes of dopaminergic neuron in the mammalian retina: dopaminergic amacrine cells and interplexiform cells [9] although Dacey [10] has argued that these represent a single cell type. Interplexiform cells may be concerned with determining the dimensions of receptive fields [11] and it has been speculated that the abnormalities in spatial vision observed in PD arise from abnormal photopic centre-surround interactions [8]. Haug et al. [7] suggested that the influence of PD on colour perception is most noticeable in signals carried by the S-cone pathway, because the S-cones are widely separated. The small bistratified ganglion cells, which are the morphological substrate of the S-cone pathway [12] have much larger receptive fields than the midget ganglion cells, and may be more dependent upon long-range spatial interactions mediated by dopaminergic interplexiform or amacrine cells.

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1.3. Purpose

The purpose of the current study was twofold: to attempt to replicate the finding that Parkinson's disease predominantly affects the S-cone pathway, and to test whether a rapid computer-controlled colour vision test was able to distinguish between PD patients and controls.

2. Methods

2.1. Subjects

Patients with PD were recruited at the Elena-Klinik, Kassel, in Germany, where they were receiving therapy as in-patients for short periods. For controls, we recruited the older staff members of the clinic, and spouses of the PD patients. Before beginning the computer test, we tested subjects with the Ishihara plates, and measured visual acuity. The following exclusion criteria were applied: congenital red-green colour vision defects, visual acuity below 6/9 in both eyes, history of diabetes, or senile dementia. All patients were receiving antiparkinsonian medication. We tested a total of 28 patients and 17 controls. The mean age of the PD group was 64.8 years (S.D. 6.8 years) and of the control group was 59.3 years (S.D. 9.0 years). All patients and controls gave their informed consent to participate in this study.

2.2. Computer-controlled colour vision test

Colour discrimination thresholds were measured using a computerized test that has been described in detail elsewhere [13–15]. The test stimulus consists of spatially discrete patches of varying size and luminance, presented on a black background (Fig. 1(a)). The luminance of each individual patch varied randomly between 8 and 18 cd m^{-2} from trial to trial. The majority of patches constituted the field and were of a single neutral chromaticity $(x, y = 0.333, 0.333)$ which remained constant across trials. A subset of patches formed the target, having the form of a C. The chromaticity of the target patches differed from that of the field patches, and was varied along a line in colour space on successive trials, according to a staircase procedure. The outer diameter of the target C subtended 4.3° of visual angle and the inner diameter 2.2°; the gap subtended 1.0°. The orientation of the target was varied randomly from trial to trial, with the gap lying at the top, bottom, left or right. Because Parkinson's disease is characterised by difficulty in initiating voluntary movements, it was decided that the subjects should indicate verbally the orientation of the C, the experimenter pressing a button on their behalf to indicate their response. Each stimulus was presented for a maximum of 8 s; if the subject did not respond in that time, an incorrect response was recorded. Discrimination was probed along two lines in colour space (Fig. 1(b)) a tritan axis, and a constant blue (red–green) axis. Each of these axes corresponds to one of the two pathways thought to carry chromatic information in the early visual system [16,17]. Trials on the two staircases were randomly interleaved.

The stimuli were generated using an Acorn A5000 computer, and presented on a Sony GDM-1936 Multiscan monitor in a darkened room. The Acorn system allowed the output of each gun of the monitor to be specified with a precision of 8 bits, which is adequate for measuring thresholds of normal subjects under our experimental conditions [15]. The monitor was calibrated with a Minolta CS-100 chroma-meter.

3. Results

The results of the test have been plotted in Fig. 2. Because our patient and control groups were not perfectly matched in age, thresholds have been plotted against age separately for the two axes (Fig. 2(b,c)) as well as the two axes against each other (Fig. 2(a)).

3.1. Correlations between age and thresholds

There is a statistically significant correlation between age and discrimination thresholds on the tritan axis of colour space for both PD patients (Spearman's $r_s = 0.529$, $P < 0.01$, 1-tailed test) and controls ($r_s = 0.492$, $P < 0.05$). There is a significant correlation between age and discrimination threshold on the constant-blue axis of colour space for PD patients ($r_s = 0.376$, $P < 0.05$) but not for controls ($r_s = 0.242$). The correlation between tritan thresholds and age is unsurprising and may reflect yellowing of the crystalline lens with age [18]. There is also a statistically significant correlation between thresholds on the two axes amongst both PD patients ($r_s = 0.645$, $P < 0.01$)and controls ($r_s = 0.539$, $P < 0.05$).

3.2. Comparison of PD patients and controls

A Mann-Whitney U test showed no significant difference in thresholds on either axis of colour space between PD patients and controls. It is true that a small number of PD patients had threshold scores outside the range of scores achieved by normal controls. However, the majority of PD patients showed no apparent impairment of colour vision on our test; and those few patients who did show elevated thresholds distinguished themselves from controls more on the constant-blue axis of colour space than the tritan axis.

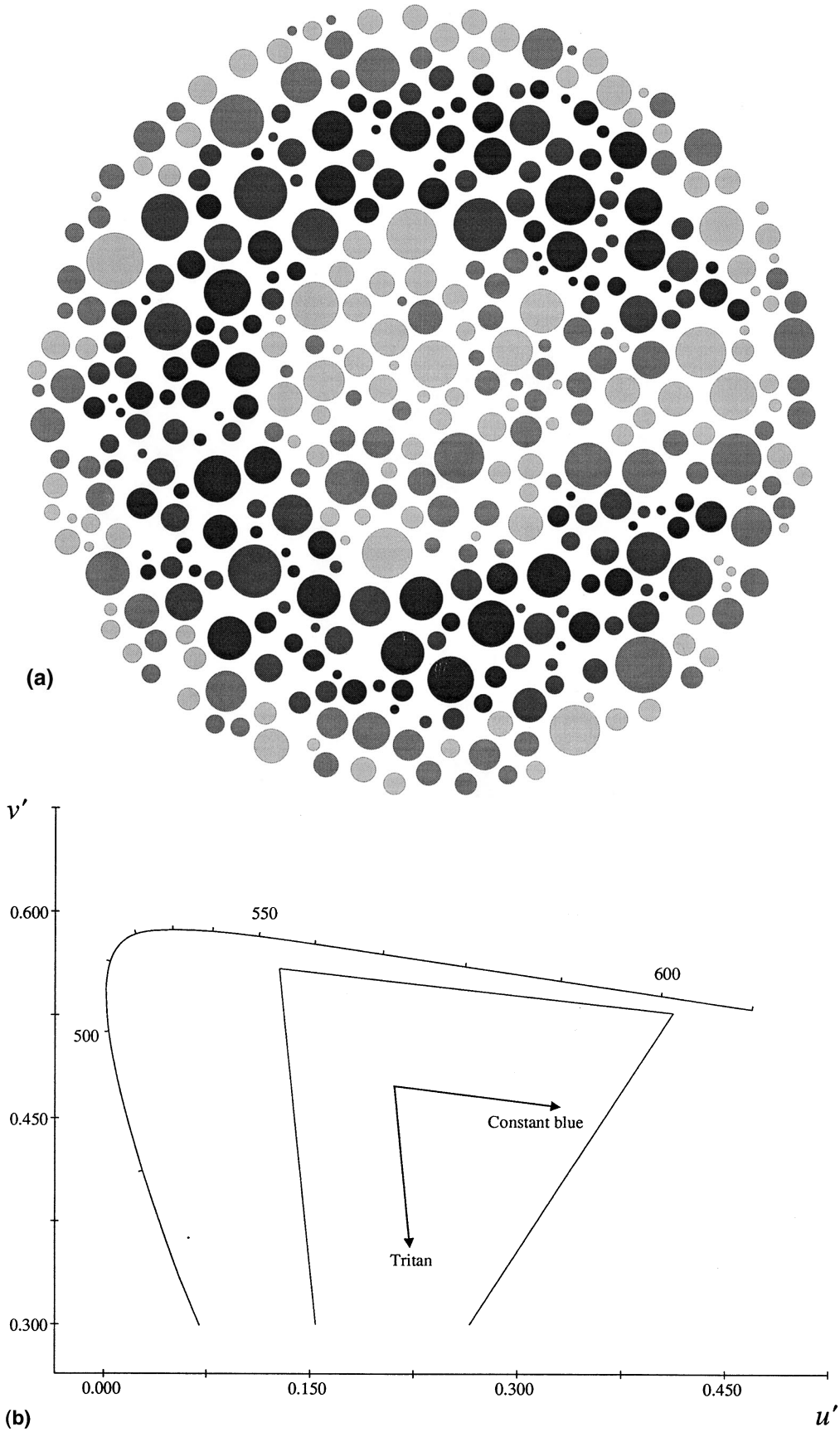

Fig. 1. (a) Schematic illustration of the stimulus used in our test. We have indicated patches of a target chromaticity by shading them a darker grey than the patches of the field. (b) A section of the u', v' colour diagram showing the two directions probed in the test. The triangle represents the gamut of the monitor.

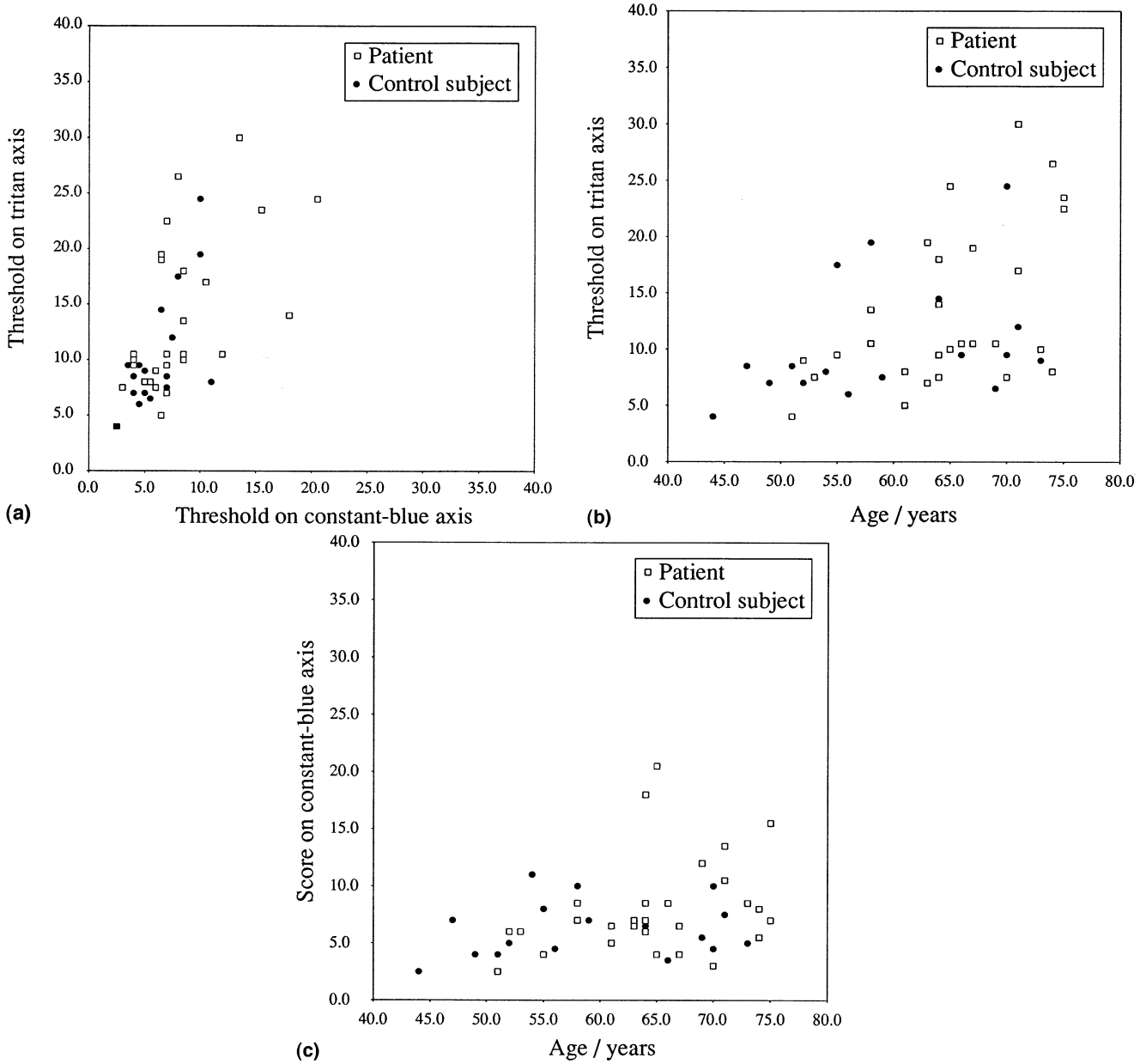

Fig. 2. Results of the test. The units for the threshold scores are thousandths of u', v' units. (a) Thresholds on the tritan axis plotted against thresholds on the constant-blue axis. (b) Thresholds on the tritan axis plotted against age. (c) Thresholds on the constant-blue axis plotted against age.

4. Discussion

The initial studies suggesting an impairment of colour discrimination in Parkinson's disease [4,5] used the Farnsworth-Munsell 100-hue test. The PD patients in these studies showed apparently severe impairments in discrimination (Price et al. [4] obtained mean error scores of 238.3 in PD patients and 73.1 in controls), a result in striking contrast to our own finding. There is an obvious explanation for this difference when one considers the nature of the Farnsworth-Munsell test, which requires the patient to make repeated movements whilst rearranging 85 coloured chips into a smoothly graduated colour series. Given that one of the characteristic symptoms of PD is difficulty in initiating voluntary movements, it is difficult to conceive of a more inappropriate test of colour vision for use with PD patients, and it is perhaps no surprise that the patients in these studies showed such apparently severe impairments. Likewise, the claim of Büttner et al. [19] that L-DOPA improves colour vision in Parkinson's disease may well be an artefact of the alleviation of motor symptoms by L-DOPA.

However, it is less easy to explain the discrepancy between the present results and those of Haug et al. [6], who found that PD patients differed significantly from controls on the tritan axis, and whose task identification of letters defined by chromaticity differences on a computer monitor-was in many respects comparable to the present task; and the two tests would be expected to have similar sensitivity. Haug et al. [7] found thresholds elevated on both protan and tritan axes using static sinusoidal gratings, but for displacement and motion thresholds it was the tritan axis that gave reliably significant results. In both these studies, as in the present one, the patients were receiving antiparkinsonian medication and thus this is unlikely to be the source of the discrepancy.

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