

Colour Group (GB) Meeting Dedicated to the Memory of:

Carl Richard Cavonius (1932—2003)

Wednesday 11 January 2011 at Gonville and Caius College, Cambridge

Authors' Abstracts

Lillie R. Cavonius

(University of Technology, Gothenburg, Sweden)

Carl Richard Cavonius was born in 1932 in America, but raised with the identity of a Finnish European. Already in early years, he showed signs of a keen intellect, winning awards for piano playing and organizing school science fairs. Although he had a deep sense of aesthetics and enjoyed art and music, he had a profound interest in a great number of subjects. He was accepted to Wesleyan in 1948 with the intent of becoming a concert pianist; luckily for science he became interested in the interactions between man and machine in this final year of undergraduate, propelling him into graduate studies at Brown (1960) under Lorrin Riggs. Fulfilling his parents' dream of returning to the old world, he held various positions in different European countries, finally settling down in Dortmund, Germany in 1976. He married Rita Catherine Euerle in 1980 and they had a daughter a year later. He died in 2003, and is remembered as a reserved person, choosing his words carefully. Those who were close he treated with warmth and generosity; but he was quick to perceive falsehood or self-aggrandizement, and applied that standard most strictly to himself.

Palmer Lecture

Oddities of early dark adaptation

Adam Reeves

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As shown by measuring thresholds for small, brief, test probes, the visual system becomes less sensitive after prolonged adaptation to a large steady field of light, and, when the adapting light is turned off, vision typically recovers sensitivity, initially quickly and then rather slowly (e.g., Baker, 1963). However, an important exception to this textbook course of dark adaptation involves the detection of short-wave test flashes, in which a long-lasting *desensitization* occurs after the offset of a long-wave adapting light (Stiles, 1949). Such desensitization was colorfully called 'transient tritanopia' by John Mollon; it is mediated by a yellow-blue (Mollon & Polden, 1979) hue-sensitive pathway which neutral adapting fields (e.g., 500 nm) do not desensitize. Desensitization reflects a rebound from polarization of a color-opponent channels pathway by the adapting field (the model of Pugh & Mollon, 1979). I will describe how in Dick Cavonius's lab I came to discover close analogues of transient tritanopia in the red-green hue pathway

(Reeves, 1981; 1983), and, at Northeastern, a less-close analogue in the luminance pathway ('transient lumanopia', Reeves & Wu, 2004). These desensitization effects are all long-lasting, all disappear at very high intensities of the adapting field, and all are heavily dependent, though in different ways, on flicker. The rebound model explains much of these yellow-blue and-red green desensitization data, excepting a flicker effect found by Loomis, and an increment/decrement effect found by Eskew; however, a temporal-filter model explains transient lumanopia. Broadly speaking, the text-book recovery in dark adaptation is perhaps the uncommon case, requiring that the field be chromatically neutral and the test have low temporal frequency content: various degrees of desensitization occur in other cases, which modeling has not yet fully explained.

Pulfrich effect: Probably due not to time delay but to phase shift

Oscar Estévez

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This work has been performed many years ago, at the laboratory of Prof. Cavonius and it has previously been shortly reported at the EUSIPCO meeting (European Signal Processing Conference, Lausanne, 1980). It is presented here by O. Estévez as a tribute to Prof. Cavonius, who designed and conducted most of the experiments, and in the hope that somebody will find an explanation for the phenomenon described.

When looking through a dark filter, while the other eye sees at the normal intensity, a pendulum is seen to describe an ellipse in space instead of moving in a single plane. This is called the Pulfrich phenomenon or effect to honour the discoverer Carl Pulfrich. It has long been held that the effect is due to a delay that the darker image produces in the eye path leading to perception. One can, by estimating the perceived depth of the elliptical path, measure the delay produced as a function of the darkening of the image. Many years ago, and for entirely different reasons, Dick Cavonius and I were measuring the phase delay introduced by darkening one eye relatively to one image held at a constant illumination. Basically our apparatus consisted of two lamps that could be modulated independently and a phase shift generator that we used to modulate one of the lamps. What we were interested in was the relative phase shift near threshold of a sinusoidal modulated light. We had previously noticed that it was possible to cancel the perception of flicker by modulating the two lamps in opposite phases: i.e. one lamp 180 degrees out of phase relative to the other. We were also pretty confident that the setting was very accurate and reproducible: both Dick and I being the subjects of the experiment. Much to our surprise we found that our phase settings were about the same for both of us and that the settings were rather constant over the range we could measure: from 0.1 Hz to nearly 50 Hz. Both Dick and I were advancing the phase of the darker eye signal by about 48 degrees per log unit light attenuation. In other words: if we presented a sinusoidal signal to one eye we had to advance the darker eye by 48 degrees (plus 180 degrees) for every log unit darkening

independently of the frequency of the signal. We were able to measure this phase shift over several log units of darkening one eye. As far as we know, this sort of effect is not a property of a linear filter and neither Dick nor I were capable of explaining this behaviour or finding a suitable model for it. It certainly means that the Pulfrich effect cannot be due to a delay in the visual pathway but rather some sort of shift in the phases of the underlying visual signal.

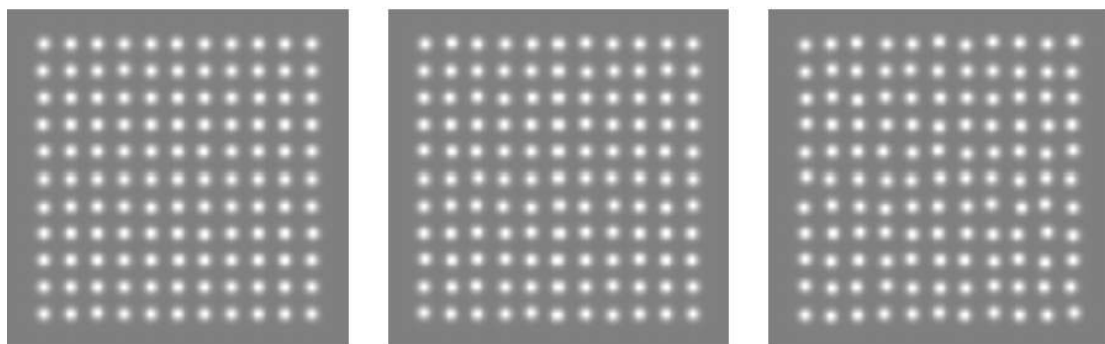
Cambridge Research Systems (CRS) sponsored Lecture

Variance discrimination for spatial regularity is impeded by irrelevant contrast variance

Michael Morgan

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Orientation 'pop out' is impeded by irrelevant variation in colour (red-green) between the oriented elements, in normal trichromats but not in protanopes or deuteranopes (see References). The fact that dichromats are not affected by colour camouflage suggests that luminance camouflage is less potent than colour camouflage, possibly because we are used to discounting luminance dappling in natural images. However, the basic mechanism for camouflage is not yet clear. I shall describe a new kind of camouflage that may throw light on this question. Previous work has shown that observers can discriminate two patterns on the basis of their orientation variance with an accuracy limited by early sensory noise and sampling inefficiency. The same is true for discriminating spatial irregularity in regular grid patterns such as those in the Figure below. Such discrimination is impaired if the dots are given random contrast polarity. The impairment is due to an increase in the early sensory noise rather than to a change in sampling efficiency.



References

Morgan, M.J., Adam, A., & Mollon, J.D. (1992). Dichromats break colour camouflage of textural boundaries. *Proc. Roy. Soc. B.*, 248, 291-295.

Morgan, M., Chubb, C., & Solomon, J.A. (2008). A 'dipper' function for texture discrimination based on orientation variance. *J. Vis.*, 8(11), 9 1-8.

The cardinal axes of colour space are not independent in colour discrimination

Marina V. Danilova

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Throughout his career, Dick Cavonius was interested in the factors that limit the discrimination of colour. In the present study, we asked whether discrimination along one of the 'cardinal axes' of colour space (Krauskopf et al., 1982, *Vision Res.*) is independent of the signal on the other axis. Specifically, we measured thresholds for variations in the relative excitation of long-wave (L) and middle-wave (M) cones, while varying the concurrent level of short-wave (S) cone excitation. Thus discriminations were always along the horizontal axis of MacLeod-Boynton space, but were tested at different positions on the vertical ordinate. Observers discriminated the two halves of a 2-deg foveal field. The luminance of each half-field was independently jittered: not only does this arrangement ensure that the observer cannot use luminance cues but also the introduction of a luminance edge between the half-fields may actually enhance colour discrimination (Hilz & Cavonius, 1970, *JOSA*). Targets were presented for 150 ms on a background metameric to D65. Discrimination of purely L/M variation was affected in a complex, but systematic way by the level of S-cone signal. At low levels of L/M, discrimination was paradoxically improved by an increase in S-cone excitation, even though the latter was common to both sides of the field. In contrast, at higher levels of L/M, discrimination was impaired when the S-cone signal increased. A possible explanation of our results is that observers exploit a neural channel not aligned with either axis of the MacLeod-Boynton diagram, a channel that is most sensitive near the subjective transition from reddish to greenish hues. This channel would draw synergistic inputs from L- and S-cones and an opposed input from M-cones.

Ageing effects in chromatic discrimination assessed by the Cambridge Colour Test

Galina V. Paramei

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Ageing effects of chromatic discrimination were assessed using the Cambridge Colour Test (CCT) in normal trichromats of five life decades, 20–69 years of age. In each age group (20+, ..., 60+), equal number of subjects of both genders were tested. The Trivector test of the CCT enabled to estimate discrimination thresholds along the Protan, Deutan and Tritan vectors of the CIE 1976 $u'v'$ chromaticity diagram; the Ellipses test estimated parameters of MacAdam ellipses (major axis, major-to-minor axis ratio, angle of the major axis) in three areas of the diagram. For each life decade, we found no gender differences in the test outcomes. With advancing age, the Trivector test showed increase of all three vectors. Significant Tritan vector increase was found in the 40+ decade. This was followed by significant elongation of the Protan vector, in the 50+ decade, and of the Deutan vector, in the 60+ decade. The Ellipses test revealed

significant elongation of the major axes of all three ellipses that reflect incremental elevation of thresholds, but no changes in the other two parameters. The findings are consistent with notion of generalised decline in chromatic sensitivity with age and of greater vulnerability of the S-cone system (Werner et al., 1990; Knoblauch et al., 2001). In addition, the present results show that the onset of noticeable deterioration of chromatic discrimination, manifesting itself as Tritan senescence effect, falls onto the 40+ decade, followed by the loss of discrimination in the L- and then M -cone systems in the next life decades.

Tetrachromacy: a new phenotype?

Gabriele Jordan

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About 12% of women are carriers of anomalous trichromacy caused by an X-linked red/green hybrid gene that encodes a cone photopigment with a spectral sensitivity somewhere between those of the normal M and L cone photopigments. Random X-chromosome inactivation ensures that the retinal mosaic of such a carrier will contain four rather than three types of cone and people have speculated (e.g. De Vries, 1948) whether individuals with such four-cone retinæ could enjoy four-dimensional colour vision. We have recently been able to lend strong support for this hypothesis (Jordan, Deeb, Bosten & Mollon, 2010), but overall our results suggest that tetrachromacy is not afforded automatically to those with four types of retinal cone. Only one out of a selected population of 31 obligate carriers performed like a functional tetrachromat. Our results are based on two psychophysical tests (hue discrimination of lights in the Rayleigh region and multidimensional scaling of pigment samples) as well as molecular genetic analyses. We conclude that tetrachromacy critically depends on factors such as the spectral separation between cone types, cone ratios and optical density. However, it is still not clear whether these factors suffice to confer behavioural tetrachromacy.

Straylight in the human eye and wavelength dependence of the light scattering processes

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Light scattering in the human eye leads to straylight, the visual phenomenon of light radiation around bright light sources against a dark background. By CIE agreement, straylight is the definition of disability glare. A few years ago a new psychophysical approach to assess straylight was developed, called "Compensation Comparison", reminiscent on the early 1970s and the flicker compensation work involving Dick Cavonius. Being more precise, quick and with control over reliability, this instigated development of the clinical instrument *C-Quant* (Fa. Oculus). It enabled to revisit some old issues, such as its

dependence on the color of the light used. Moreover straylight levels were found to depend on the color of the iris. Wavelength dependence of straylight has remained somewhat of an enigma since Stiles in 1929 supposed it to have the same strong Rayleigh type λ^{-4} wavelength dependence as small particle light scattering (the blue of the sky). However, experiments failed to show λ dependence for straylight, leading to conclusions that light scattering in the eye does not originate from small particles. Yet there is strong experimental evidence for such λ dependence from *in vitro* study of light scattering by donor eye lenses and *in vitro* as well as *in vivo* studies on the cornea. With the new method, straylight from 457 to 625 nm was studied in 32 subjects aging 21-81 years, with a wide range of pigmentations. Spectral dependence of straylight was found to depend on pigmentation of the eye. The psychophysical straylight phenomenon shows λ dependence that is in accord with data on individual light scattering processes in the eye. The λ^{-4} type of light scattering in the cornea and young lens is revealed only in the young well pigmented eye. With less pigmentation a strong red dominated component originating from reflectance of the fundus and transmittance through the eye wall adds to it, negating this λ dependence. These results also explain the finding that straylight is greater in blue eyes as compared to dark eyes.

Lagerlunda

John D. Mollon

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and

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Some 8% of men exhibit an inherited deficiency of colour vision. Yet for several decades before 1875, colour signals were used internationally in railway systems without any screening of employees. The introduction of screening is usually traced to a fatal accident that occurred in Sweden on the night of 15th November, 1875. The scene of the accident was the estate of Baron Lagerfelt in Östergötland, but the critical events were played out at Linköping (the normal passing place for the northbound and southbound expresses) – and at Bankeberg (a small station to which the passing place was reassigned at a few minutes' notice). First to arrive at Bankeberg, the northbound express slowed almost to a halt, but then inexplicably accelerated forwards towards the Lagerlunda estate, despite a sequence of signals from the stationmaster, Uno Björkelund, and a lineman, Oskar Johansson. Soon after the accident, the ophthalmologist Frithiof Holmgren suggested that the driver of the northbound express, Andersson, or his oiler, Larsson, had been colour blind. Neither survived to be tested. Using the manuscript records of the subsequent trial and other archival materials, we have re-examined the role of colour blindness in the Lagerlunda incident and conclude that the accident cannot be attributed to colour blindness alone. Yet the accident undoubtedly had a central role in the introduction of colour vision testing by European and North American railroads. To persuade the railroad management to introduce universal screening of

employees for colour blindness, Holmgren used a dramatic *coup de theatre* and some unashamed subterfuge.
