Visual Psychophysics and Phenomenology

Its possible relation to biology
Visual psychophysics

• Long history (19\textsuperscript{th} C)

• Fechner, Helmholtz, James C Maxwell

• Early identification of the fundamental properties/characteristics
color
“As it is almost impossible to conceive each sensitive point of the retina to contain an infinite number of particles, each capable of vibrating in perfect unison with every possible undulation, it becomes necessary to suppose the number limited, for instance to the three principal colours, red, yellow and blue".

Thomas Young, 1802
19th C. color matching experiment

Key observation

\[ W \equiv aX + bY + cZ \]

color matching equation
19th C. color matching experiment

Key observation

\[ W = aX + bY + cZ \]

color matching equation
In 1852 Hermann Von Helmholtz suggested that only 3 receptors are needed for colour vision, each broadly tuned to wavelength (*trichromacy theory*).

He suggested that perceived colour depends on the relative strength of their activations.
Human visual pigments: microspectrophotometric results from the eyes of seven persons

By H. J. A. Dartnall\textsuperscript{1}, J. K. Bowmaker\textsuperscript{2} and J. D. Mollon\textsuperscript{3}

\textsuperscript{1}Laboratory of Experimental Psychology, University of Sussex, Brighton, BN1 9RH, U.K.
\textsuperscript{2}School of Biological Sciences, Queen Mary College, London, E1 4NS, U.K.
\textsuperscript{3}Department of Experimental Psychology, University of Cambridge, Cambridge, CB2 1TN, U.K.

(Communicated by H. B. Barlow, F.R.S. – Received 6 June 1983)

The material for this work was obtained from seven eyes removed because of malignant growths. Foveal and parafoveal samples of the retinas were taken and transverse measurements were made of the absorbance spectra of the outer segments of the rods and cones, using a Liebman microspectrophotometer.
Absorption spectra of single human cone receptors
Figure 2. The mean absorbance spectra of the four human photoreceptors. Squares, the blue cones ($\lambda_{\text{max}} = 419.0 \pm 3.6$ nm, mean of 5); filled circles, the rods ($\lambda_{\text{max}} = 496.3 \pm 2.3$ nm, mean of 39); triangles, the green cones ($\lambda_{\text{max}} = 530.8 \pm 3.5$ nm, mean of 45); plain circles, the red cones ($\lambda_{\text{max}} = 558.4 \pm 5.2$ nm, mean of 58). The curves are all exactly the same shape and were constructed from the mean human data of table 4. Note inset scale of wavelengths.
Individual cone sensitivities to wavelength
Neural adaptation
Ewald Hering
19th C

• Colors are arranged in an opponent relation
Red green opponency in Monkey retina

R+  G-  R-G+
ENERGY, QUANTA, AND VISION

BY SELIG HECHT, SIMON SHLAER, AND MAURICE HENRI PIENNE†

(From the Laboratory of Biophysics, Columbia University, New York)

(Received for publication, March 30, 1942)

I

Threshold Energies for Vision

The minimum energy required to produce a visual effect achieves its significance by virtue of the quantum nature of light. Like all radiation, light is emitted and absorbed in discrete units or quanta, whose energy content is equal to its frequency ν multiplied by Planck’s constant h. At the threshold of vision these quanta are used for the photodecomposition of visual purple, and in conformity with Einstein’s equivalence law each absorbed quantum transforms one molecule of visual purple (Dartnall, Goodeve, and Lythgoe, 1938). Since even the earliest measurements show that only a small number of

Visual psychophysics
one rod - one quanta
ENERGY, QUANTA, AND VISION*

BY SELIG HECHT, SIMON SHLAER, AND MAURICE HENRI PIRENNE†
(From the Laboratory of Biophysics, Columbia University, New York)

(Received for publication, March 30, 1942)

I

Threshold Energies for Vision

The minimum energy required to produce a visual effect achieves its significance by virtue of the quantum nature of light. Like all radiation, light is emitted and absorbed in discrete units or quanta, whose energy content is equal to its frequency ν multiplied by Planck's constant h. At the threshold
Pattern ERG
Multi-focal ERG

Invented by
Erich Sutter
Possible approaches

• psychophysics $\rightarrow$ ERG $\rightarrow$ cellular biomarker?

Example
3 studies of major depression
Vision in depressive disorder

EMANUEL BUBL¹, LUDGER TEBARTZ VAN ELST¹, MATTHIAS GONDAN², DIETER EBERT¹ & MARK W. GREENLEE²

¹Department of Psychiatry and Psychotherapy, Albert-Ludwigs-Universität, Freiburg, Germany, and ²Department of Experimental Psychology, University of Regensburg, Regensburg, Germany

Abstract
Background. Reduced dopaminergic transmission has been implicated in the pathophysiology of major depression. Furthermore, dopaminergic neurotransmission plays an important role in the physiology of visual contrast sensitivity (CS). To test the hypothesis that altered dopaminergic neurotransmission plays a role in major depression we measured contrast sensitivity in patients with major depression and in healthy control subjects. Methods. Twenty-eight patients diagnosed with major depressive disorder were compared to 21 age-matched control subjects on their ability to detect a Gabor target with slightly elevated luminance contrast embedded in seven equi-contrast distracters. Results. Contrast discrimination thresholds were significantly elevated in unmedicated and medicated patients with major depression compared to control subjects, at all pedestal contrast levels tested. Conclusions. Contrast discrimination performance is reduced in depressive patients and might reflect a state of altered dopaminergic neurotransmission.

Reduced contrast sensitivity
Tested using psychophysics
Pattern electroretinogram in depression

Reduced pattern ERG