is a potent serotonin antagonist and psychotomimetic compound, its psychotomimetic action may be related to, but is not necessarily dependent upon, its serotonin antagonism. Bromo-lysergic acid diethylamide, for example, is a potent serotonin antagonist, yet has little psychotomimetic action. It is, however, significant that the compound, 10-methoxyharmalan, is a potent antagonist of the myotropic action of serotonin and probably is a competitive antagonist. It is also the most potent derivative of serotonin, so far tested, that causes conditioned animals to make mistakes in an avoidance-escape schedule.

Unequivocal evidence for the production of 10-methoxyharmalan in the body has not been obtained, but it must be noted firstly that it can be derived from serotonin in three steps, the first two of which have been shown to occur in vivo, namely N-acetylation (*8*), O-methylation (*4*), and cyclodehydration. Secondly, a minor metabolite of melatonin previously noted (*9*) does not give the characteristic color reaction for indoles, and thus could be a cyclic derivative. Lastly, the highest concentration of serotonin has been found in the pineal glands of psychotic patients (*10*). These factors, in addition to the evidence presented here, tend to support the hypothesis that some psychotic states could be due to an endogenously produced harmala alkaloid (*11*, *12*).

WILLIAM M. MCISAAC
PHILIP A. KHAIRALLAH
IRVINE H. PAGE

Research Division, Cleveland Clinic Foundation, Cleveland, Ohio

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Eyestalk Movements Induced by Polarized Light in the Ghost Crab, Ocypode quadrata

Abstract. Differential visual sensitivity to vertical and horizontal linear polarization is shown in the light-induced eyestalk deviations of *Ocypode quadrata*. Responses with the *e*-vector vertical averaged about 6° greater than those with *e*-vector horizontal. This difference approximates the relative eyestalk deviation induced by unpolarized light intensities having a ratio of 3:1.

Although many arthropods have been shown to respond to linearly polarized light (*1*, *2*), relatively little is known about the ability of higher crustaceans to see such polarization (*3–5*). Consequently, experiments were initiated on various decapods to help remedy this situation. The present report (*6*) describes differential responses to polarized light measured in terms of eyestalk movements in the ghost crab, *Ocypode quadrata* (Fabricius). Related experiments on learning and menotactic orientation in lobsters and crabs are reported elsewhere (*7*, *8*). Except for studies on orientation of the whole animal, previous work on responses to polarization has been limited to observations on eye position in *Daphnia* (*2*, *9*) and on electrical responses of the eye in insects (*10–12*) and horseshoe crabs (*13*).

The position of the eyestalks of decapod crustaceans is quantitatively dependent on the intensity and the incident angle of the prevailing illumination (*14*). Maximum deviation is elicited by unilateral horizontal light parallel to the animal's transverse axis. Furthermore, the extent of this eyestalk light response depends on the degree of statocyst excitation (*15*). With one statocyst removed, maximum eyestalk deviation evoked by light occurs when the gravity-induced shearing force in the remaining statocyst is minimized.

In many decapods this is achieved when the animal is tilted around its longitudinal axis about 30° towards the side without a statocyst. Consequently, in the present experiments the left statocyst was removed 2 to 5 days before use, and the crabs were fixed in a clamp holding them in this position for maximum eyestalk response (Fig. 1).

The light source was an automobile headlight (*16*) directed first through a small aperture and then through a rotatable polarizing filter (Polaroid HN38). This provided a narrow beam (1 to 2 mm in diameter) of white light nearly 100 percent linearly polarized. The tests reported here were limited to vertical and horizontal positions of the *e*-vector (plane of polarization). Full intensity at the eye was 800 lux without the polarizing filter and 620 lux with the polarizing filter; a lower intensity of 280 lux was obtained by using neutral filters made of uniformly exposed photographic film. Special care was taken in using this setup to eliminate reflection-refraction artifacts which might provide intensity cues for the plane of polarization.

The stimulating light beam was directed laterally at the crab's left eye (about 4 mm in diameter), which was fixed in position with paraffin to maintain a constant angle of light incidence. The response measured was the position (angle, α, between its long axis and the horizontal) of the right eyestalk, which was freely movable and not illuminated by the test light (Fig. 1).

Four individual mature specimens 25 to 30 mm in carapace width, were tested in this setup. Two types of comparisons were made. First, eyestalk responses were compared for vertical and horizontal positions of the stimulus *e*-vector with the intensity at 620 lux. Second, the intensity ratio of unpolarized light necessary to produce the same difference in eyestalk deviation as the two planes of polarized light produced was determined.

The results of the first experiment are summarized in Table 1. The mean eyestalk angles (averaged from 169 measurements under each condition) are shown for individuals exposed to vertical and to horizontal *e*-vectors. In all four animals eyestalk deviations were greater by statistically significant amounts (*P* values for the no-difference

Table 1. Influence of vertically (v) and horizontally (h) polarized light stimuli on the angle (α) between eyestalk axis and a horizontal plane. Means of the readings for each animal are given as well as their standard deviations (s) and differences ($\alpha_v - \alpha_h$).

$\alpha°$				$\alpha_v - \alpha_h$
v	s	h	s	
Animal 1 (71 observations)				
71.8	1.0	66.4	0.98	5.4
Animal 2 (57 observations)				
89.3	0.6	80.3	1.7	9.0
Animal 3 (16 observations)				
91.3	1.1	85.6	1.1	5.7
Animal 4 (25 observations)				
90.2	0.7	85.3	1.0	4.9
Mean				
85.7	—	79.4	—	6.3

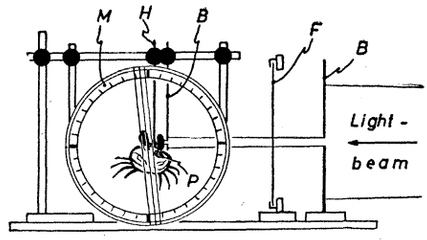

Fig. 1. Method of measuring the angle (α) between the right eyestalk axis and a horizontal plane when a small essentially parallel light beam stimulates the left eye laterally. *B*, diaphragm; *F*, linear polarizer; *H*, clamp; *M*, protractor; *P*, paraffin fixing the left eye.

hypothesis varied from .001 to .0001) with vertical polarization than with horizontal polarization of the same photometric intensity. On the average vertical polarization was more effective by 6°.

The intensity ratio ($I_1 : I_2$) of unpolarized light required to match approximately the differences in eyestalk deviations ($\alpha_v - \alpha_h$) evoked by the two polarization planes was found in a few experiments on one individual to be 3:1. For these results I_1 was about 800 lux, $\alpha_v - \alpha_h$ was 5.6° and $\alpha_{I_1} - \alpha_{I_2}$ was 5.2°. Variance of the readings was such that the differences in eyestalk deviations were significant in the two cases.

Because of the care taken to eliminate intensity artifacts, the observed difference in the effectiveness of the two planes of polarized light may be taken as evidence that the eye itself was acting as a polarized light analyzer. Earlier attempts to demonstrate polarized light sensitivity in decapod crustaceans have provided one somewhat doubtful report (*17*) or negative results (*5*); but since the present work was completed, extensive positive data have been obtained on orientation responses to polarized light by many kinds of decapods (*8, 18*). Also, previous efforts to demonstrate differential phototactic effects of vertically and horizontally polarized light failed with *Tenebrio* larvae, the beetle *Tetraopes*, and the terrestrial isopod *Cylisticus* (*19*).

At present neither the mechanism nor the biological significance of the polarized light responses reported here is known. Either a peripheral or central origin is possible for the observed lack of radial symmetry in sensitivity to plane of polarization (*5, 20*). In the insect *Notonecta*, a bilateral symmetry of the ommatidium is apparently involved since the amplitude of the electroretinogram in this plane of symmetry is about 22 percent greater than with the *e*-vector 90° away (*11*). The only hypothesis for the mechanism of polarized light sensitivity consistent with the known facts requires individual retinular cells to be differentially sensitive to *e*-vector positions (*3, 5, 10–12, 21*). In dipteran insects, intracellular electrodes have demonstrated the required type of photoreceptor element (presumably a single retinular cell) with response maxima and minima to plane polarized light 90° apart (*12, 21*). The intensity differences necessary to match these maxima and minima are rather similar to those found in the present data (*22*).

HERMANN SCHÖNE
HEDWIG SCHÖNE

Bermuda Biological Station, St. George's West, and Max-Planck-Institut, für Verhaltensphysiologie, Seewiesen, Germany

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General Method of Plotting Kinetic Data for Reactions of Any Order

Abstract. A method is presented for obtaining from kinetic experiments both order of reaction and rate constant by means of a single straight-line graph, in contrast to previous methods, which require several steps including more than one graph or repeated trial-and-error calculations whenever there is no prior knowldege of the order of reaction.

Commonly used methods for evaluating reaction rate constants from experimental data either presuppose a knowledge of the reaction order or proceed by assuming an order in trial-and-error fashion. If, as frequently happens with complex and fractional-order reactions, the correct assumption is not made on the first trial, the computations can become tedious. This is true also of the direct determination of orders by the differential method of van't Hoff, which requires at least two separate plots as well as measurements of slopes often difficult to obtain with precision. Other direct methods, utilizing half-life periods or initial velocities for a series of reactant concentrations, are dependent on the availability of these additional experimental data for different initial concentrations.

All these procedures share the shortcoming of requiring a combination of several steps or plots before both order and rate constants can be evaluated. If the requisite number of trials is not made, the lack of sensitivity with respect to order inherent in some of these methods (for instance, the same set of data may give reasonably straight appearing lines if plotted according to the equations for more than one reaction order) can be the cause of inaccurate or misleading statements of the "order" of a reaction (see *1*).

These considerations make it desirable to find a way of obtaining both kinetic constants in a single step. Referring to the general differential equation for a simple reaction

$$dx/dt = k(a - x)^n \qquad (1)$$

(where a is the initial concentration; x is the amount reacted, in the same concentration units as a; t is the elapsed time; k is the rate constant; and n is the order of reaction), it does not appear unreasonable to search for a straight-line plot of some suitable simple functions of the reaction variables such that the two parameters of the line (slope and intercept) would uniquely determine the two constants