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BIOLOGIY
(ETHOLOGY)

On the Orientation of the House Fly (*Musca domestica* L.) towards White Light of Various Intensities

by

J. A. CHMURZYŃSKI

Presented by J. KONORSKI on May 7, 1967

Despite extensive studies, continued for several decades, the knowledge of the photic responses in insects is still far from complete. Our knowledge is particularly limited as regards the reaction of choice in a maze of white lights in dependence on their different intensities. This applies both to the phenomenological aspect and the mechanism of this reaction. It is the more strange as numerous studies (cf., e.g., [1], [6]—[8] and [10]—[12]) on the insects' colour vision have been carried out in T- or Y-shaped mazes and, in many cases, conclusions were drawn, concerning their spectral sensitivity, on the basis of the choice of coloured light under such conditions. Hardly any authors took the trouble to study the response of the animals examined to white light of various intensities before concluding on the relative subjective brightness of coloured light [2]—[4].

The problem of a double choice of the sources of white light of various intensities is, however, interesting in itself. This is precisely the reason why studies have been undertaken on the behaviour of house fly populations under experimental conditions similar to those applied by Cameron to the same object of studies, as well as by Bertholf to the honeybee.

Material and methods

Flies of the "Moscow" strain, made available to the present writer by the State Institute of Hygiene in Warsaw, were bred in cubic (25×25×25 cm.) vivaria and fed a diet of boiled milk, prepared from powdered milk (1 g. per 100 ml.) together with a 0.1 M glucose solution which assures a maximum longevity of flies [5]. Eggs, collected from the milk, were put into a roll of cheese cloth soaked in milk and, together with it, placed in a bowl, covered with perforated paper. The bowl with its content was subsequently put into a thermostat, in which a temperature of 25°C and relative humidity of 60—70 per cent were maintained.

Four to twelve-day-old mixed populations of both male and female flies were used for the experiments.

In addition to the cage with flies (A), referred to above, the experimental set consisted of a Y-maze (B) and two sources of light (C and C′), together with accessory devices, shown in Fig. 1.

Inside-frosted, 50 W, 12 V lamps with a colour temperature of 3.100°K, (C. Zeiss, Jena), were the sources of light. The illumination, measured — by means of a MDLx luxometer with a sele-

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nium cell — in the window (O), 0.05 m. in diameter, cut in a lamp casing (D), was changed by sliding the lamps along optical benches. For the purposes of the present work, two series of experiments were carried out: with 147 lux and 225 lux standard light. In the first experimental series,

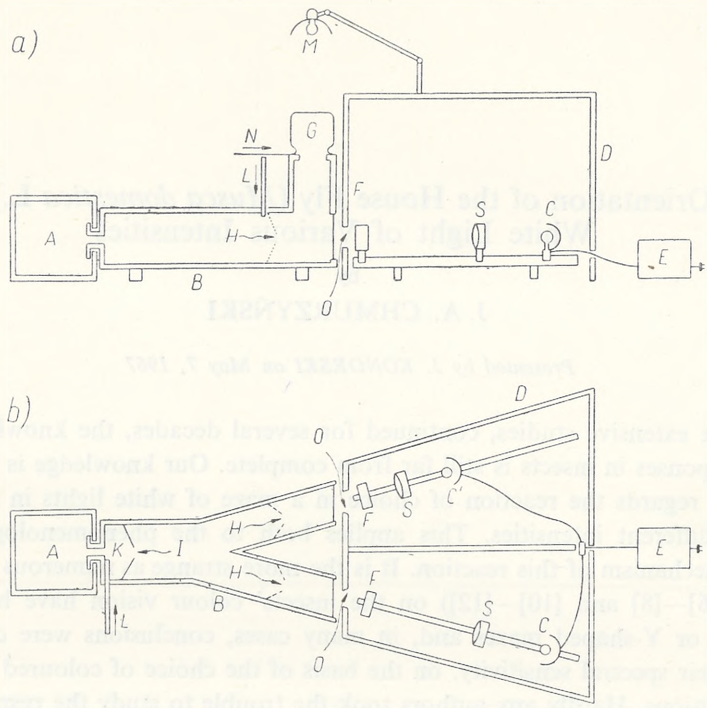

Fig. 1. a) — lateral view; b) — top view

Arrangement of equipment: *A* — cage with flies, *B* — Y-shaped maze, *C* — lamp and *S* — lens, emitting an almost parallel bundle of light beams, mounted on an optical bench in a casing, painted mat-black on the inside; current stabilized by a constant-voltage regulator *E*; *F* — heat filter. The remaining explanations are given in the text

the illumination corresponded to that, applied by Cameron [4], that is, $H = 10.78\ \mu W/0.00005$ sq. m. The following calculation was used to find the ilumination in lux (e_0): $e_0 = H \cdot K_m$, (where: K_m — photometric equivalent of illumination which, according to Oleszyński [9], amounts to $680\ ^{lm}/W$)

and, therefore, $$e_0 = \frac{0.0000108\ W}{0.00005\ \text{sq. m.}} \cdot 680\ ^{lm}/W = 10.8 \cdot 10^{-6} W \cdot 13.6 \cdot 10^{6}\ ^{lx}/W \approx 147\ \text{lux}.$$

In both experimental series, the intensity of the variable light was changed within the limits of 1/16 and 4 times the value of that of the standard light, its values mostly fulfilling the conditions of the geometric progression: $a_n = 2^{(n-1)}$, where n assumes integral values, falling within the limits of $-5 \leqslant n \leqslant 3$.

The flies, not starved and adapted to darkness for 1 hour, were taken in the darkened cage to the darkened laboratory at about 10 a.m. A temperature of 22±2°C and relative humidity of 65±5 per cent was maintained. The cage (A) was connected with the maze (B) whose entrance was opened after switching on the lights (C and C′), placed along the optical axes of the maze branches, diverging at the angle of 30°. Under such conditions, flies flew to the "porch" (K), then, through slot (I), they reached the maze shaft and — from the point of choice which in our maze was more or less equally distant from the ends of the branches as in Cameron's [4] experiments — they flew or walked to the branches, passing through the openings of mesh funnels (H), which made their return difficult, and they gathered near the panes opposite to the windows (O) of the lamp casing. After 10 min., opaque shutters (L) were drawn and, at the same time, the C and C′ lights

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were switched of with a simultaneous switching on of lamp (M), illuminating the jars (G) which were mounted on the upper openings of the chimneys, situated at the ends of the branches. Thus, a phototactic passage of flies to the jars was caused and, thereafter, the jars closed with a piece of cardboard (N), were removed and replaced by empty ones.

The flies in jars were anaesthetized by means of carbon dioxide or nitrogen hypoxide and after counting, they were placed in a new cage, so that each fly was only once used for a given experiment. After removal of all the flies from the maze branches, the experimental conditions were re-established for a period of 10 min. and frequently, after a repeated choice of lights by the flies, for a third time.

In contradistinction to Cameron's experiments, inactive flies were not eliminated but, instead, all flies were compelled — by blowing the air from a hair-drier through the maze entrance — to go all the way to the funnels. The entire procedure, from adapting the flies to darkness to counting of the last flies caught, took about 5 hrs. Each test was repeated 2—4 times, each time with different mutual situation of the lights. For statistical reasons, different populations of flies were used for each run (the same flies were, however, used for different tests).

Results

Series 1. The aim of this series was to compare the results, obtained during the experiments with populations of flies with those, obtained by Cameron [4] who experimented on few, responsive, repeatedly choosing specimens. The intensity of the standard light corresponded to the conditions of his test ($e_0 = 147$ lux).

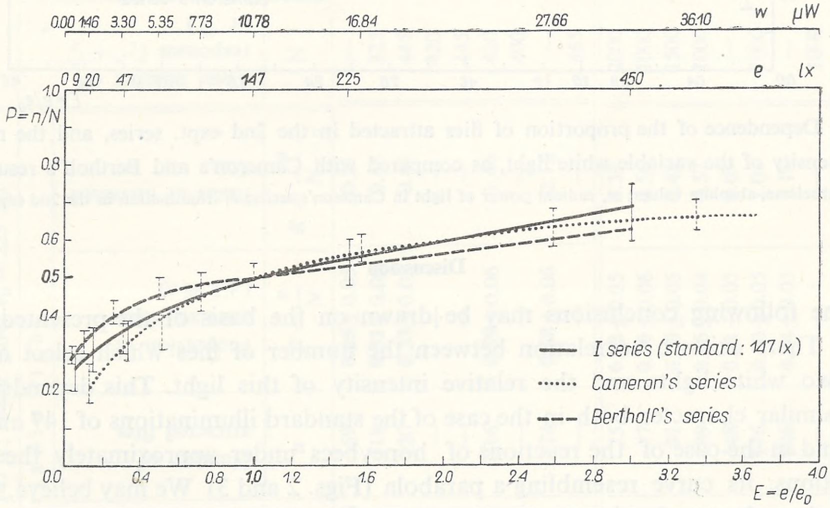

Fig. 2. Correlation of proportion of insects, attracted by the white light of variable intensity with the relative intensity — lower abscissa

Upper abscissae — absolute values: w — radiant power of light in Cameron's series, e — illumination in the first experimental series. Vertical bars determine the significance interval for $p = 0.05$. Here and further — an original elaboration of Cameron's and Bertholf's results

Under our experimental conditions, the flies displayed in fact the same trend as those in Cameron's experiments and honeybees in Bertholf's [2] tests, that is, the more intensive the experimental light as compared with the standard one, the greater the number of flies, attracted by this light (Fig 2). The results of this experimental series are presented in the upper part of the Table which, for the purpose

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of comparison, also contains the data obtained by Cameron. The last-named data are calculated, jointly for male and female specimens, on the basis of his Table XIV.

Series 2. Standard white light of 225 lux was applied. The Table—lower part—also includes Bertholf's [2] results, from his experiments with honeybees, although — as it may easily be calculated — the standard light, applied in his tests had an approximate illumination of 0.85 lux. In this series a relation was also observed to exist between the light selected by the flies and its relative intensity (Fig 3).

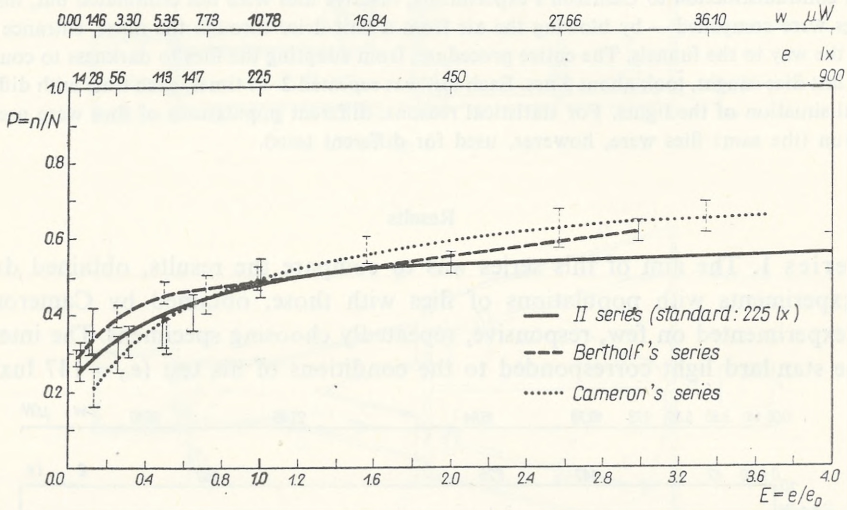

Fig. 3. Dependence of the proportion of flies attracted in the 2nd expt. series, and the relative intensity of the variable white light, as compared with Cameron's and Bertholf's results

Upper abscissae, absolute values; *w*, radiant power of light in Cameron's series; *e*, illumination in the 2nd expt. series

Discussion

The following conclusions may be drawn on the basis of the presented data.

1. There exists a correlation between the number of flies which select one of the two white lights and the relative intensity of this light. This dependence is of a similar character both in the case of the standard illuminations of 147 and 225 lux, and in the case of the reactions of honeybees under approximately the same conditions, its curve resembling a parabola (Figs. 2 and 3) We may believe, therefore, that the mechanism on which such choice is based is identical in different diurnal photophilous insects.

2. Despite fundamental similarities, we cannot, however, consider the character of the dependence to be identical, either in the two series of our experiments or in comparison with the data cited from the literature. Although, in some cases the differences are small, they all are significant at the adopted level $p = 0.05$.

For this reason, the dependence, we are interested in, cannot be presented in the form of a simple, universal, mathematical formula. The linear correlation, suggested by Bertholf, i.e.:

$$\log R = m \log E + b \quad (1)$$

TABLE

Original expts (stand.: $e_0 = 147$ lx; lower part: $e_0 = 225$ lx)						Cameron's results, below-Bertholf's results					
	Variable light						Variable light				
Total number of responses	Intensity of light (illumination in lx)	Relative intensity of light	Number of attracted flies	Proportion of attracted flies ($\pm 1.96\,\sigma$)	Ratio of attracted flies	Total number of responses (♂ + ♀ or ♀)	Intensity of light (radiant power in μW)	Relative intensity of light	Number of attracted insects	Proportion of attracted insects ($\pm 1.96\,\sigma$)	Ratio of attracted insects
N	e	$E = \frac{e}{e_0}$	n	$P = \frac{n}{N}$	$R = \frac{n}{N-n}$	N	w	$E = \frac{w}{w_0}$	n	$P = \frac{n}{N}$	$R = \frac{n}{N-n}$
276	9	**0.06** = 1/16	69	**0.25**±0.05	0.21	—	—	—	—	—	—
375	20	**0.14** ≈ 1/8	118	**0.31**±0.06	0.46	325	1.46	**0.13** = 1/8	67	**0.21**±0.05	0.25
367	47	**0.33** = 1/3	120	**0.33**±0.05	0.49	445	3.30	**0.33** = 1/3	151	**0.34**±0.04	0.51
—	—	—	—	—	—	420	5.35	**0.50** = 1/2	149	**0.35**±0.05	0.55
—	—	—	—	—	—	445	7.73	**0.72**	206	**0.46**±0.05	0.86
364	225	**1.53**	216	**0.59**±0.06	1.44	420	16.84	**1.56**	225	**0.56**±0.05	1.15
—	—	—	—	—	—	400	27.66	**2.57**	253	**0.63**±0.05	1.72
256	450	**3.13**	174	**0.68**±0.06	2.12	—	—	—	—	—	—
—	—	—	—	—	—	465	36.10	**3.34**	308	**0.66**±0.04	1.96
268	14	**0.06** = 1/16	75	**0.28**±0.05	0.39	2000	—	**0.05**≈1/16	576	**0.29**±0.02	0.40
214	28	**0.13** = 1/8	77	**0.36**±0.06	0.56	1000	—	**0.11**≈1/8	333	**0.33**±0.03	0.50
303	56	**0.25** = 1/4	91	**0.30**±0.05	0.43	1500	—	**0.25**=1/4	597	**0.40**±0.03	0.60
519	113	**0.50** = 1/2	189	**0.36**±0.04	0.57	1000	—	**0.50**=1/2	459	**0.46**±0.03	0.85
364	147	**0.65**	148	**0.41**±0.05	0.69	—	—	—	—	—	—
351	225	**1.00**	176	**0.50**±0.05	1.01	1000	—	**1.00**	502	**0.50**±0.03	1.01
938	450	**2.00**	506	**0.54**±0.03	1.14	—	—	—	—	—	—
—	—	—	—	—	—	1000	—	**3.00**	625	**0.63**±0.03	1.67
462	900	**4.00**	262	**0.57**±0.05	1.31	—	—	—	—	—	—

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cannot claim such a role. Even, if it fits the material discussed, the results of Bertholf, of Cameron and those obtained in series 1, it is not true for our series 2 (Fig. 4). Besides, for statistical reasons, it is more convenient to deal with a proportion (*P*)

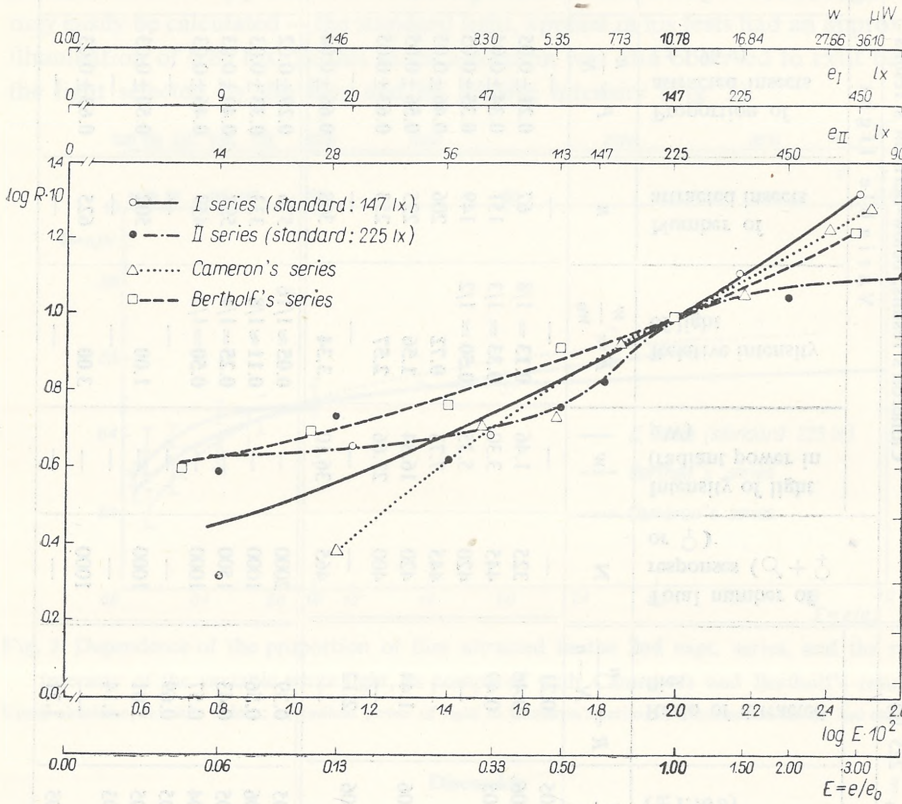

Fig. 4. Correlation of the logarithm of the relative number of insects' responses with the logarithm of the relative intensity of the variable white light

Upper abscissae — absolute values: *w* — radiant power of light in Cameron's series, e_I — illumination in series 1, e_{II} — illumination in series 2

than with a ratio (*R*). If we apply *P*, Cameron's results adequately fulfill the following linear correlation:

(2) $$P = k \log E + c$$

and the results of Bertholf's experiments and of both our series (cf. Fig. 5) to a considerable extent fulfill it, too. However, in this case also differences are recorded in the response of the insects, in particular at stronger intensities of the variable light. Causes of the observed differences are difficult to explain. Probably, a certain indication may be provided by the comparison of our results, obtained in the first and second experimental series whose divergence is clearly illustrated by Fig. 4. Different intensities of the standard light constituted the only significant difference in the conditions under which these results were obtained.

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For the time being, it seems to be the safest to treat the dependence, we are interested in, as a sort of a parabola which — with more intensive standard light — seems to increase less quickly than the parabola describing the results, obtained with a smaller intensity of light. It is quite possible that the proportion of insects,

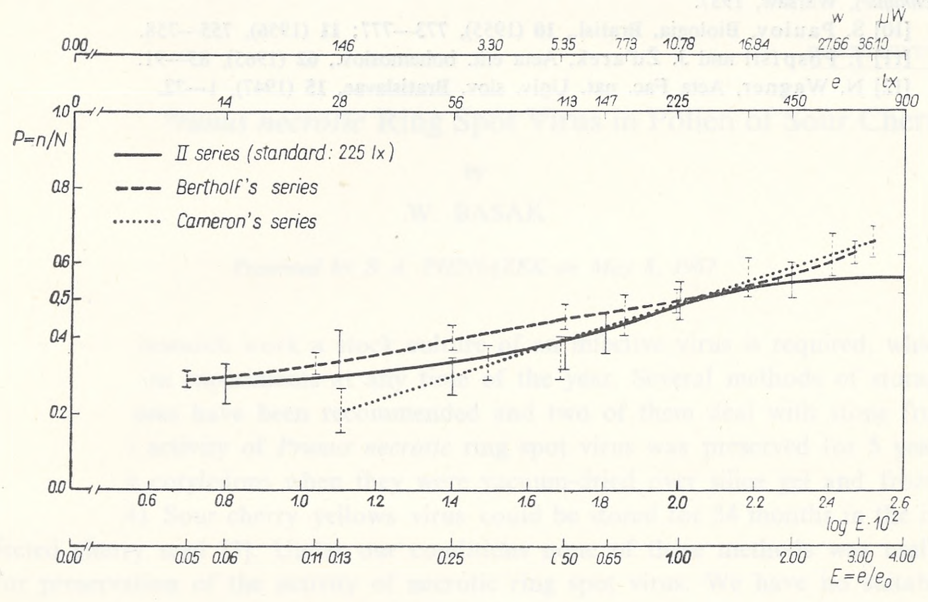

Fig. 5. Semilogarithmic plot of the dependence of the proportion of insects, attracted by the variable white light and the logarithm of its relative intensity in series 2, as compared with Cameron's and Bertholf's results

Upper abscissae — absolute values, cf. Fig. 4

choosing a brighter light may have a limited maximum value at a very high intensity of this light (cf. Fig. 3). It requires further studies.

The steeper slope of the curve from Cameron's data, as shown in Figs. 4 and 5, may result from the lack of inactive individuals in his trial.

3. Thus, it would be premature to develop a general hypothesis concerning the mechanism of the choice of lights by the populations of insects in a two-branch maze.

I would likie to express here my thanks to Miss A. Krzemińska, who was kind enough to provide the flies and give helpful advice as to their breeding.

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TABLE DES MATIÈRES

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