PHOTOPOSITIVE RESPONSES OF MUSCA DOMESTICA AND LUCILIA SP. TO MONOCHROMATIC LIGHTS

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Abstract. The specimens *Diptera*: *Musca domestica* and *Lucilia sp.* adapted to dark were offered two monochromatic lights of different wavelengths. *Musca domestica* always preferred the light of a shorter wave out of two monochromatic equiquantum lights. Six color regions presumably qualitatively different were distinguished for this fly: violet-blue, blue, green, yellow-green, orange and red. *Lucilia sp.* exhibited no preference to certain ranges lying on both sides of the region maximally saturated. Nevertheless this fly well distinguished three colors ranges: violet-blue, green-yellow and orange-red.

INTRODUCTION

Investigations on insects color vision were initiated in the second decade of this century. Karl von Frisch (1914) was the first who discovered insects ability to color discrimination. This finding became later one of the main problems of studies taken up by many workers. However, they observed great differences in color perception. This fact might be connected with the life mode of particular insects. To test such a possibility experiments were carried out on two *Diptera* species. One of them, *Musca domestica*, is a synanthropic insect, whereas imago of *Lucillia*, the other one, can often be found on flowers, feeding on nectar and pollen.

METHODS

Subjects. Experiments were carried out on several days old imagines of insect, before they achieved their reproductive ability. Pupae *Musca domestica* were supplied by the Institute of Organic Industry in Warszawa and put into tulle cages measuring 32 cm in length, 14 cm in breadth and 26 cm in height. Imagines of insects were fed with boiled milk and with aqueous solution of glucose; water was also supplied. Relative humidity of the culture space was kept on the level of 60–70%.

The culture *Lucilia sp.* was maintained from June to October. Insects were captured on meat bait on which they laid eggs. Larvae were kept at a temperature of about 28°C in relative humidity of approximate 70% in containers with a layer of dry sand at the bottom in which the pupae subsequently aggregated. Imagines were kept in tulle cages, the same as for house fly. The insects were reared on milk, glucose solution and water.

Apparatus. Experiments were carried out in a maze especially constructed for this work. The experiments on the preference to colored light were executed subjecting the insects to simultaneous action of two monochromatic lights of different wavelength. Lights were directed on the insects in such a way that each light illuminated one eye of the experimental animal at the moment of performing the choice.

The maze (Fig. 1) was composed of a wooden middle part with an inlet corridor and two lateral ones, leading to the plexiglass containers.

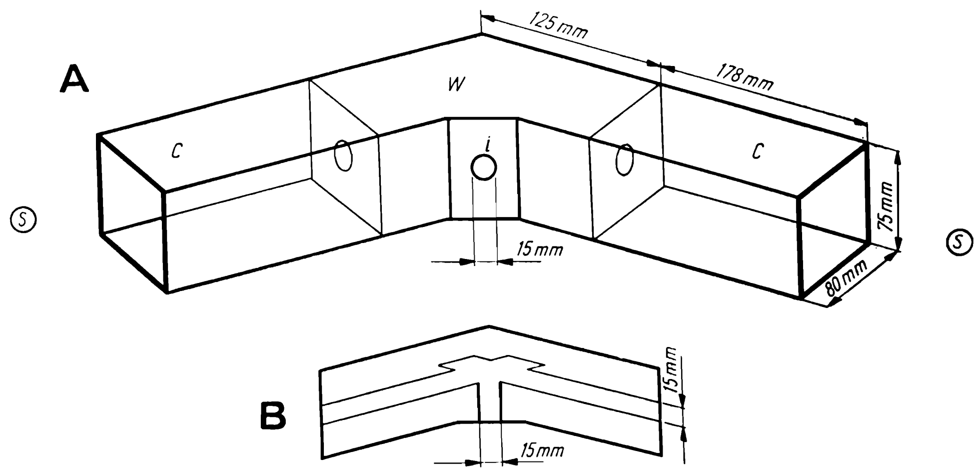

Fig. 1. The maze to examine the color preferences by insects. *A*: the front view of the maze; *w*, wooden midddle part; *c*, plexiglass container; *i*, inlet; s, the light sources. *B*: the passages of the wooden part of the maze.

The entrance to the maze, as well as the two lateral passages were 15 mm in diameter. Their inside surface was covered with soot. The passages were supplied with blackened recesses in the wooden part lying beyond the choice point (Fig. 1*B*). This assured avoiding color mixing in the passages. The angle between the maze arms hindered the return of insects from the container of the maze after the light choice was performed to the opposite light because the insects could not see the radiation from the opposite light source.

Light sources. As light sources xenon 150 w Tungsram bulbes were placed in special covers. The optic system and spherical mirror of the lamps permitted to gain an almost parallel light beam (5% of divergence), with an intensity of about 18,000 lx. The heat filters eliminated thermic radiation. The colored lights within the range of 400 nm to 650 nm were produced by means of Zeiss interference filters type IF. Filters of the following wavelengths were applied: 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650 nm. The light intensity was measured with of a selen luxmeter type MD 1x standarized in the energy units for each successive intensity of the interference filters applied. Measurements of illumination were made in the place of radiation choice prior to inserting the wooden middle part of the maze. The minimal difference of wavelength of lights applied in the experiments amounted to 25 nm, the maximal to 250 nm. Equiquantum lights were applied to eliminate the influence of light intensity on the course of the experiment.

Procedure. Experiments were performed in a darkened room. About 100 *Lucilia* specimens and 100–200 house flies were let into the maze for one trial. The insects were used after adaptation to darkness. The whole group was collected in a test tube which was placed at the entrance to the maze. The insects went from the tube into the entrance passage of the maze and chose one of the presented lights. After all of the tested insects went into the plexiglass containers, they were anesthesized with carbon dioxide for a short period of time and counted. Statistical significance has been assumed on the level $p = 0.5$. The same subjects were never used again on the same day.

RESULTS

Experiment I

The aim of the first experiment was to study the flies responses to a sequence of various pairs of colored equiquantum lights, differing in wavelengths of 25 nm in each pair.

As shown in Fig. 2 and 3 the house fly failed to choose any pair of lights within the region of 400–450 nm. However, it was found that this animal well discriminates the wavelength of light 475 nm from the radiation of 450 nm as well as from 500 nm. The lights of the wavelength 500 and 525 nm are equally attractive but they are preferred than the radia-

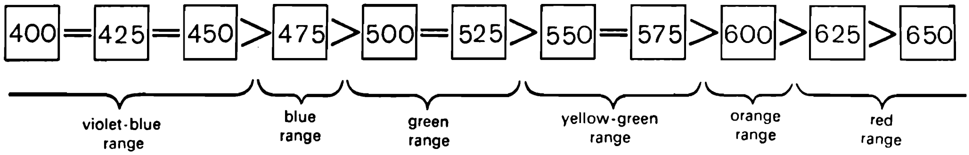

Fig. 2. Spontaneous choice of successive spectrum colors by *Musca domestica*. The symbols = and > denote the lack and presence of preference respectively.

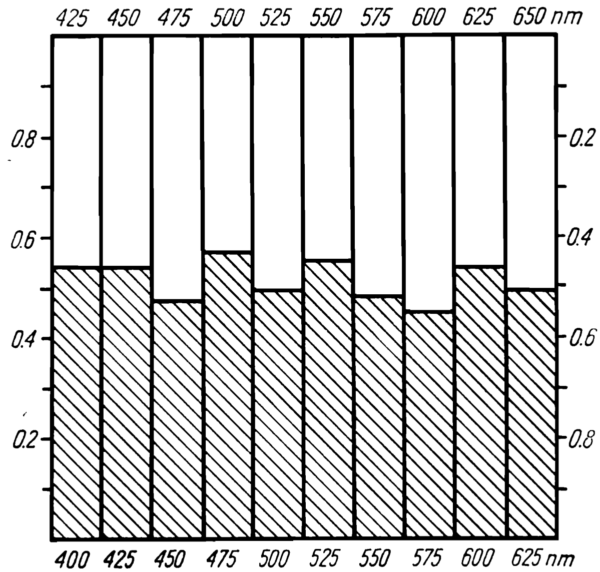

Fig. 3. Choice of monochromatic lights of wave difference 25 nm by *Musca domestica*. Abscissa: wavelengths in nanometers. Ordinate: the proportions of alternating light choice.

tion of 550 nm. The last pair of lights in which no preference was observed are the lights 550 and 575 nm. The radiations tested within the region from 575 nm to 650 nm are distinguished from each other.

Figure 4 and 5 illustrate the spontaneous choice of separate monochromatic lights of *Lucilia*. It distinctly selects the radiation 475 nm than 500 nm and prefers the radiation 575 nm to 600 nm. In the range of violet lights (400–450 nm) no significant preference to any of those lights was confirmed. Similar phenomena occur in the range of 500–575 nm. Basing on the behavior of flies, three groups of lights which are evidently discriminated (one from another) by *Lucilia* may be distinguished: the violet-blue range, the green-yellow, and the orange-red range.

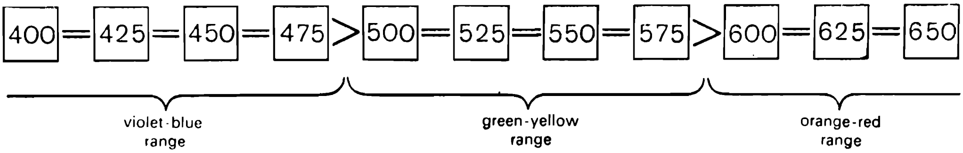

Fig. 4. Spontaneous choice of successive spectrum colors by *Lucilia sp.* The denotations as in Fig. 2.

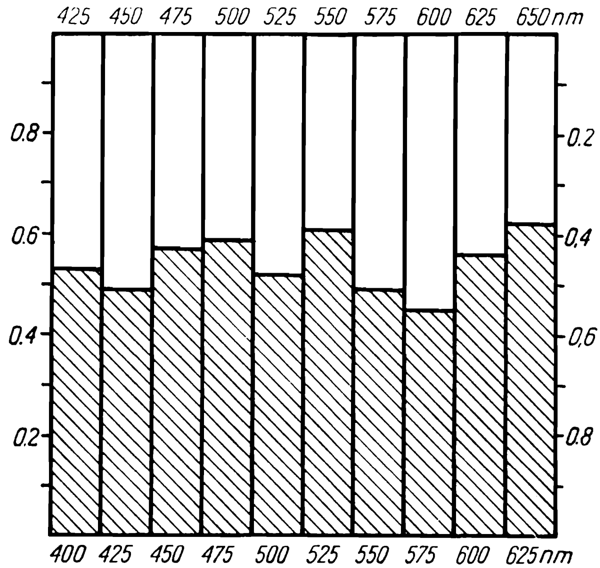

Fig. 5. Choice of monochromatic lights of wave difference 25 nm by *Lucilia sp.* The denotations as in Fig. 3.

Experiment II

This experiment concerned the comparison of the light of a given wavelength and of a standard intensity, successively with the monochromatic equiquantum lights of different wavelength — the so-called variable lights. The light of the 500 nm wavelength was selected as standard based on the data of Autrum (1960). According to him this part of spectrum presents for *Calliphora erythrocephala* a band of the most saturated color and is well discriminated by it from all other light wave ranges. In this experiment a clear preference of *Musca domestica* for the short wave part of spectrum was confirmed. As illustrated by Fig. 6, the preference for the short wavelength is proportional to the difference between wave-

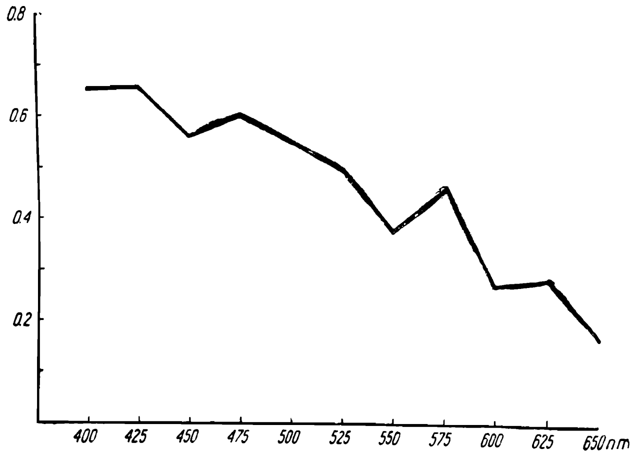

Fig. 6. Choice of monochromatic lights of the standard 500 nm *by Musca domestica*. Abscissa, the wavelenghts compared successively with the standard radiation. Ordinate, proportions of alternating ligth choice.

lengths of the radiations studied. Similarly as in the house fly, *Lucilia* prefered the lights of shorter wavelength and this preference rises together the difference of distance between the wavelengths (Fig. 7). The standard light is equally attractive at the accepted level of significance as the lights of waves 525 nm for *Musca domestica* and of 525 nm and 550 nm for *Lucilia*.

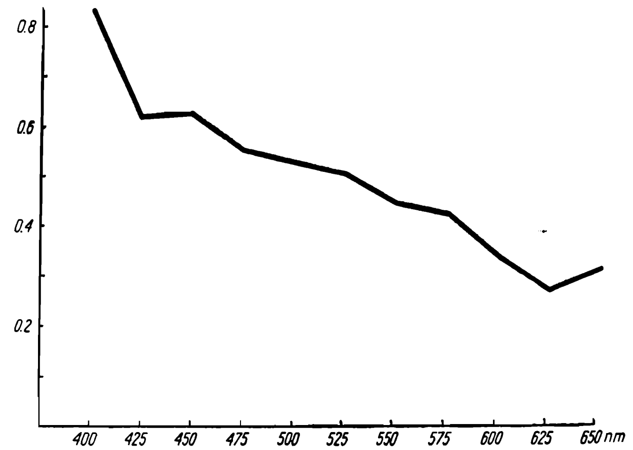

Fig. 7. Choice of monochromatic lights at the standard 500 nm by *Lucilia sp.* The denotations as in Fig. 6.

Experiment III

This experiment is based on the results of both preceding ones. Nine different pairs of lights were comparted. They belonged to the regions well discriminated one from another. The aim of this experiment was to find such a pair of lights, which would be equally attractive to the animals. It was found that *Lucilia* did not show the preference to any light in pairs 475 and 600 nm, 450 and 525 nm, 475 and 525 nm (Fig. 8). On the other hand, *Musca domestica* showed the preference to a shorter light-wave in all the pairs of lights tested.

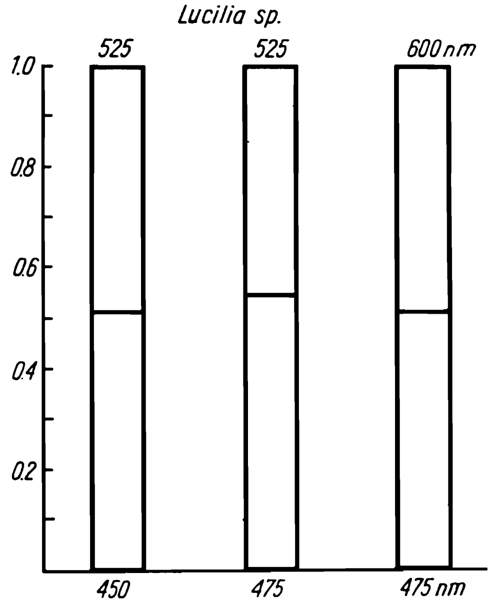

Fig. 8. Choice of different pairs of monochromatic equiquantum lights by *Lucilia sp.* (only those light pairs are presented to which *Lucilia* responded in the same manner).

DISCUSSION

Ždárek and Pospišil (1966 distinguished three types of color vision in insects using the method of spontaneous light choice: the one type characteristic for aphids, with a maximal preference in the yellow-green range, the other type occurring in flies with maximal attraction preference in the violet-blue range and the last type occurring mostly in beetles with maximal reaction to ultraviolet. It follows from these experiments on the innate reactions to the monochromatic lights that flies prefer the short wave range of light spectrum. A marked preference to short waves is shown in house flies.

On the other hand, *Lucilia* responded in the same manner to some radiations occurring on both sides of the maximal color saturation range, as was stated by Autrum (1960). The green-yellow range is well discriminated from the red one by the house fly and *Lucilia*, which could be related with the maximal sensitivity of these animals in those ranges according to the opinion of some authors (Autrum and Stumpf 1953, Mazokhin-Porshnyakov 1960*b*).

It seems that in the direct dependence between attractiveness of radiation and sensibility it is not a rule that the insects must have an eye on it. However, when the preference to some kind of light is observed, it follows that the animal well distinguishes the lights compared.

According to Mazokhin-Porshnyakov (1960*ab*), the poor distinguishing of lights in the violet-blue range is associated with the action of single receptor at his range. A much better distinction expressed in a doubtless preference, occurs in the case of the light pairs, each of them belonging to a different range than the three principal ones distinguished by insects. Perception of them depends on different receptors.

Autrum and Stumpf (1953) indicate the region between 480 and 500 nm the wavelengths of light as the most highly saturated for *Calliphora* and well distinguishable by this insect from the other kinds of light. The results of the experiment are in conformity with the data of Autrum and Stumpf, because the 500 nm radiation used is well distinguished from the violet and blue lights as well as from the yellow, orange and red ones. A rather distinct preference occurring in the 575–625 nm range, in which the radiation on wavelength 600 nm is discriminated by *Lucilia* from the yellow and *Musca* from yellow and red light (625 nm) support data of Autrum and Stumpf, who found a good distinction of colors in the 580–630 nm range of wavelengths. Similarly, experiments with 475 and 600 nm as well as 450 and 525 nm light pairs appeared to be equally attractive for *Lucilia*. Autrum (1960) noted that on both sides of the maximal saturation range of spectrum lights were laid to which *Calliphora* reacted in a similar manner.

The controversy between the results of the present study and data of Autrum and Stumpf is seen in the short-wave part of the light spectrum. In this region, a lower sensibility of the *Calliphora* eye was found by electrophysiological study. The permanent preference for shorter wave light as was observed in the present study might be recognized as a distinct preference of flies for color hues of this range, i.e. as chromotaxis.

However, some results of the present study differ from data found earlier by Autrum and Stumpf and Mazokhin-Porshnyakov. Probably due to quite different experimental methods. In electrophysiological study, the responses of the insects eye receptors were observed. In experiments of the present study, the animal response depended not only on the properties of the visual analyser, but also on various physiological and ecological factors as well.

The violet colors are practically always preferred to all others and if more differences between the studied wavelengths take place, this preference is especially clear. The experiments on the animal behavior carried out by many authors also support the attractiveness of colors of the short-wave part of spectrum and the special part of ultraviolet radiation in the course of the insects life. E.g. Pospíšil (1962) studied the spontaneous choice of colors in house fly. His experiments concerned color lights and color plates also. He confirmed a clear preference for the lights of the violet-blue group to the green, yellow and red ones which was also supported by the present study. However, his opinion that the attractiveness of green, yellow and red lights maintains on the same level — cannot be accepted. In this species, a high ability to distinguish the radiations of long-wave spectrum has been observed in our experiment. Cameron (1938) assumes that ultraviolet (365 nm) is the region of the highest sensitivity of the house fly. According to him the attractiveness of radiation is decreasing gradually from this point to both sides of the spectrum.

Autrum and Burkhardt (1960), Burkhardt and Autrum (1960), Mazokhin-Porshnyakov (1960*ab*) also demonstrated the existence of a distinct peak of sensitivity in the ultraviolet region, however, a little lower than that in the green range of spectrum.

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