Natural Sciences

Original article

Spectral sensitivity of the compound eyes and behavioral attraction to light stimuli with different intensities and wavelengths in *Lucilia sericata* (Meigen, 1826) from Colombia

Sensibilidad espectral de los ojos compuestos y atracción conductual a estímulos lumínicos con diferentes intensidades y longitudes de onda en *Lucilia sericata* (Meigen, 1826) de Colombia

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Abstract

Lucilia sericata (Meigen, 1826) (Diptera: Calliphoridae) is a synanthropic fly with a worldwide distribution that pollinates plants and is relevant in medical, veterinary, and forensic sciences. *L. sericata* is a diurnal species whose vision plays an important role in spatial orientation. Here we evaluated the electrophysiological responses (ERG) of *L. sericata*'s compound eyes in adults of both sexes from Colombia and their behavioral attraction to LED lights with different wavelengths. The ERG revealed a dichromatic vision with peaks at blue (450 nm) and green (510-530 nm) wavelengths in individuals of both sexes. Behavioral experiments with a two-sided light tunnel showed that both sexes were mainly attracted to blue, white, and red lights of different intensities (0.34, 0.15, and 0.034 $\mu W/cm^2$). Attraction to the lights decreased at lower intensities; however, attraction to blue, white, and red lights was still observed. The electrophysiological and behavioral results we obtained in the laboratory were complementary and explain how Colombian untrained *L. sericata* adults interact with their environment using mainly the sunlight wavelengths reflected under natural conditions.

Keywords: Electroretinogram; Color vision; Blowflies; Light tunnel assay; Visual signals.

Resumen

Lucilia sericata (Meigen, 1826) (Diptera: Calliphoridae) es una mosca sinantrópica con distribución cosmopolita que poliniza plantas y tiene, además, importancia médica, veterinaria y forense. *L. sericata* es una especie diurna, por lo que la visión juega un papel importante en su orientación espacial. Evaluamos aquí los ojos compuestos de adultos de ambos sexos de *L. sericata* de Colombia desde el punto de vista electrofisiológico, y su atracción comportamental hacia luces LED con diferentes longitudes de onda. Los estudios electrofisiológicos mostraron una visión dicromática con picos en longitudes de onda azul (450 nm) y verde (510-530 nm) en individuos de ambos sexos. Los experimentos comportamentales realizados en un túnel luminoso de dos vías evidenciaron la atracción de las moscas hacia luces azules, blancas y rojas en las diferentes intensidades evaluadas (0,34, 0,15 y 0,034 $\mu W/cm^2$). La atracción a las luces disminuyó frente a las intensidades más bajas; sin embargo, la atracción hacia las luces azules, blancas y rojas se mantuvo. Los resultados electrofisiológicos y comportamentales en condiciones de laboratorio son complementarios y explican cómo los individuos colombianos no entrenados de *L. sericata* interactúan con su medio ambiente utilizando las longitudes de onda del sol reflejadas bajo condiciones naturales.

Palabras claves: Electrorretinograma; Visión a color; Califóridos; Ensayo en túnel luminoso; Señales visuales.

Introduction

Lucilia sericata is a fly from the Calliphoridae family distributed worldwide (**Smith**, 1986). Calliphoridae members are well known for frequently visiting plant inflorescences to obtain nutrients that facilitate ovary maturation (**Brodie *et al.***, 2015); they are also highly associated with copronecrophagous habits because they develop in vertebrate corpses and inhabit mammals' excrements (**Artamonov**, 2012). From a medical and veterinary point of view, *L. sericata* is important because it is involved in the transmission of bacteria, viruses, and protozoa, and also because they are facultative ectoparasites causing myiasis in animals and, occasionally, in humans in Australia, Europe, and North America (**Graczyk *et al.***, 2005; **Sotiraki & Hall**, 2012). Besides, *L. sericata* larvae have been used for larval therapy to remove necrotic tissues from the skin (**Church & Courtenay**, 2002). Finally, in forensic sciences, blowflies' larvae have been used as a post-mortem time indicator because, in their adult stage, they are one of the first insects able to colonize corpses (**Figueroa & Linhares**, 2002; **Saigusa *et al.***, 2009).

Under natural conditions, compound eyes in adult insects can receive a wide spectrum of direct and reflected lights that stimulate the photoreceptor cells that generate different behavioral responses (**Stavenga**, 2002; **Borst**, 2009; **Sanes & Zipursky**, 2010; **van der Kooi *et al.***, 2021). Searching for food, refuge, resting, oviposition, and landing places, mating, predator evasion, and flight are some of the behaviors mediated by light detection in flies (**Douglass & Strausfeld**, 1996; **Stavenga**, 2002; **Diclaro *et al.***, 2012; **Eichorn *et al.***, 2017; **van der Kooi *et al.***, 2021).

The electroretinogram (ERG) technique has been implemented in insects to understand the physiology of their compound eyes (**Crescitelli & Jahn**, 1939); this has allowed recording the electrophysiological responses of compound eyes and ocelli exposed to light stimuli (**Autrum & Galxwitz**, 1951; **Autrum**, 1958; **Naka & Kuwabara**, 1959; **Goldsmith**, 1965; **Yinon**, 1970; **Briscoe & Chittka**, 2001; **Kirchner *et al.***, 2005; **McNeill *et al.***, 2016; **López-Reyes *et al.***, 2022; **Yilmaz & Spaethe**, 2022; **Ortiz *et al.***, 2023). Several electrophysiological studies have detected spectral sensitivity to blue, green, and ultraviolet (UV) lights using ERG in Thysanoptera, Lepidoptera, Diptera, Hymenoptera, and Hemiptera insects (**McCann & Arnett**, 1972; **Peitsch *et al.***, 1992; **Kirchner *et al.***, 2005; **Stavenga & Arikawa**, 2006; **Döring & Chittka,** 2007; **McNeill *et al.***, 2016; **Lopez-Reyes *et al.***, 2022; **Yilmaz & Spaethe**, 2022; **Ortiz *et al.***, 2023).

Döring & Chittka (2007) suggested that knowing the spectral sensitivity of the photoreceptor in an animal allows predicting the quantity of information sent to the brain when an object is seen. However, the spectral sensitivity of compound eyes does not allow predicting an insect's behavioral response to a light stimulus. For instance, it has been shown that horse-flies (Tabanidae) with spectral sensitivities to blue (480 and 515 nm) are attracted to blue, red, and dark objects (**Allan *et al.***, 1987).

Given its ecological role and its convenient rearing, *L. sericata* flies have been used to understand the anatomy (**Douglas & Strausfeld**, 1996) and landing (**Goodman**, 1960) and spectral responses to visible and polarized light in different brain regions (**McCann & Arnett**, 1972); responses of photoreceptor cells to lights flicking at different frequencies (**Ruck,** 1961), and the attraction to inflorescences (**Brodie *et al.***, 2015), color cues (**Brodie *et al.***, 2015; **McFadden & Hans**, 2019), and color traps for the control and study of population densities (**Public Health Monograph**, 1955; **Hutchinson**, 2000).

Having in mind the ecological, medical, and forensic importance of *L. sericata* and the lack of information about color attraction in Colombian populations, we determined the spectral and threshold sensitivity of compound eyes in local males and females. We complemented the electrophysiological information with behavioral results under laboratory conditions to establish the attraction of untrained males and females to LED light stimuli at different intensities and wavelengths.

Materials and methods

Insects

We attracted *L. sericata* wild males and females between 9:00 and 15:00 hours using 250 g of liver from cows and captured them with entomological nets in El Jaboque wetland (4°44'16.12" N, 74°8'55.79" W), west from Bogotá. We identified the flies with the taxonomical keys of **Beverley** (1991) and **Amat** (2008).

All the insects evaluated were reared from the individuals collected in the field, and maintained at 24 ± 2 ºC, $75 \pm 10\%$ relative humidity, and a 12:00/12:00 (light/darkness) photoperiod in an insect colony at Universidad de los Andes. Flies were fed with fresh chicken liver, fruit-flavored sweets, and cotton dipped in water. Fresh chickens' liver was used as oviposition substrate; 1 to 6 days after emergence, adults were used in all behavioral and electrophysiological experiments.

Electrophysiological experiments

Flies were immobilized inside a 10 μl micropipette tip cut at 2.5 cm to expose only their heads. Heads were fixed ventrally in paraffin wax to the micropipette tip. We used black paint to cover the ocelli and the left eye in all the flies. Then, the insects were located in a metallic box painted in black (18 x 18 x 15 cm) to avoid exposition to external light. This metallic box was also fixed inside a Faraday cage to reduce electrical interference. All recordings were done between 9:00 and 16:00 hours at 20 ± 3 °C and 45% relative humidity.

Indifferent tungsten electrodes sharpened electrolytically were inserted in the vertex while recording electrodes were located close to the equatorial region of the right compound eye. To ensure the electrical connection between the recording electrode and the surface of the compound eye, we used a drop of conductive gel (Signagel®, Parker).

Electrical signals were digitalized at a sampling rate of 20 kHz with a PowerLab/8SP (ADInstruments) and the LabChart 7 software. DC electrical signals were recorded from the compound eye at a range of 2 mV with a 10 Hz filter. Stimuli signals were recorded as mentioned above but in a 5 V range.

We used the PowerLab/8SP stimulator function to control light stimuli start and end. Eight unidirectional 5 mm diameter LEDs at different wavelengths were used in the experiments (**Table 1**). LEDs (400, 450, 510, 530, 580, 600, 640, and 900 nm) were controlled with an independent electrical circuit, and their spectral emission was measured with a spectrophotometer (Ocean Optics USB4000-UV-VIS) and the Spectrasuite software. LEDs intensity was measured with a radiometer (ILT1400 International Light Technologies) at a 10 cm distance, i.e., the distance between the LED and flies' compound eyes.

Sensitivity thresholds were determined by measuring the electrophysiological response in four flies of each sex stimulated with a 450 nm LED at 0.09, 28.4, 52.9, 180, and 376 μW/cm² intensities.

Spectral sensitivities were determined in five flies of each sex adapted to darkness, yellow, or white light conditions. LEDs at 28.4 μW/cm² located inside the metallic box at 5.0 cm of the dorsal part of flies' heads were used for selective adaptations to yellow and white light conditions (**Table 1**). Before the experiments, flies were adapted selectively for 20 min, after which they were stimulated with ten 300 ms light flashes (**Figure 1**) at 5 s interpulse intervals. In addition, a time of adaptation of 5 min was allowed between each of the different wavelengths tested.

We measured ten "on-response" (**Figure 1B**) ERG components in *L. sericata* adults' compound eyes, obtaining a mean for each wavelength tested. The data were normalized with the following formula:

$$(DV \times 100) / DV_{max}$$

where DV is the mean value for the "on-response" components and DV_{max} is the highest voltage difference measured "on-response" in all tested wavelengths. A "relative response" ranging between 0 and 100 was then obtained.

Table 1. Spectral emission and intensity of the LEDs used in the electrophysiological and behavioral experiments in untrained *Lucilia sericata* adults from Colombia

LED type	Color	Wavelength		Intensity (µW/cm²)
		Peak (nm)	**Range (nm)**	
Unidirectional, 5 mm	Violet	400	380-420	
	Blue	450	430-500	
	Dark green	510	480-550	
	Light green	530	500-580	28.4*
	Yellow	580	550-620	
	Orange	600	560-630	
	Red	640	610-670	
	Infrared***	900	830-?	
1 W	Yellow	588	560-620	0.34**
	Red	630	580-640	0.15** 0.034**
	Blue	460	440-520	28.4*
	White	450 and 530-560	420-730	

*Electrophysiological experiments, **Behavioral experiments, *** Light intensity was not measured.
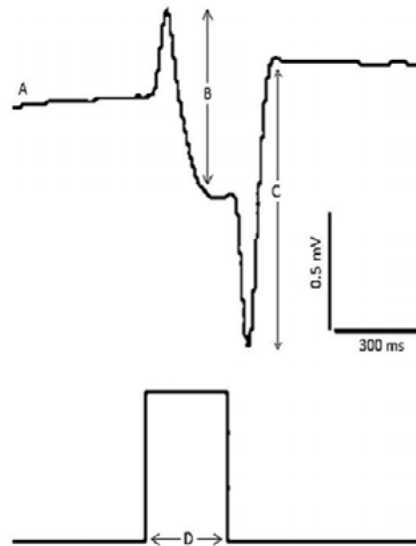

Figure 1. Electroretinogram (ERG) response in wild untrained adults of *Lucilia sericata* from Colombia. Upper trace: Biphasic male ERG response showing changes in voltage: (**A**) Resting potential. (**B**) "On-response" and (**C**) "Off-response". Lower trace: Characteristics of the stimulus in amplitude and duration (**D**).

Behavioral experiments

All behavioral experiments were done between 9:00 and 16:00 hours in a dark room at 23 ± 1 °C and 75 ± 10% relative humidity. We used a two-sided light tunnel made from 60 mm diameter PVC tubes modified from **Diclaro *et al.*** (2012) (**Figure 2**). The vertical tube was 9 cm long and the two horizontal ones were 35 cm. The two horizontal arms ended in two styrofoam boxes of 40 L. Inside the boxes, a transparent plastic trap captured all flies attracted to one of the three 1 W LEDs (white, blue, or red) located at the bottom of the
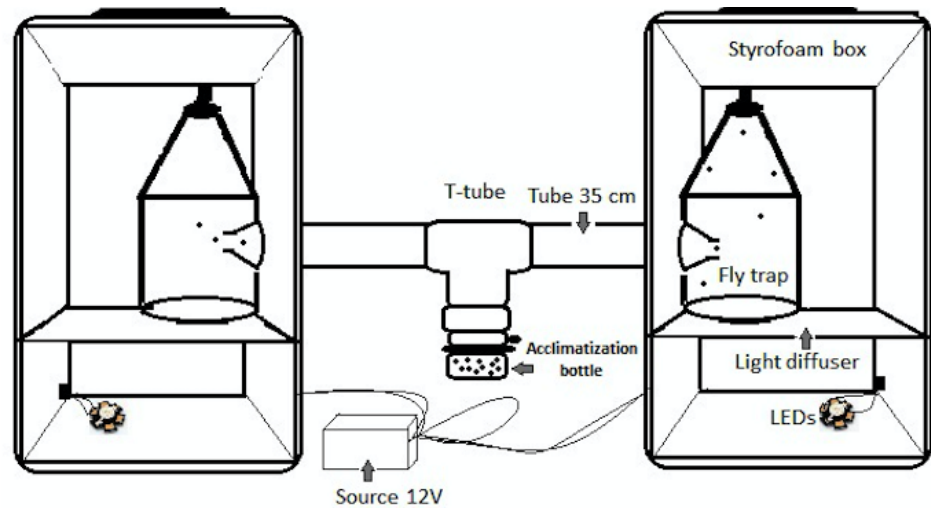
Figure 2. Experimental arena showing the two-sided light tunnel used to test the behavioral responses of wild untrained *Lucilia sericata* from Colombia in response to light stimulation. The two-sided light tunnel (PVC tubes) consisted of an acclimatization acrylic bottle and two styrofoam boxes. Inside each styrofoam box, a light source (LEDs), an acrylic light diffusor, and a transparent plastic trap to capture flies were placed. A 12 V electrical source was connected to LEDs located on both sides.

box as light stimuli. An acrylic sheet (Ajover L026100-122-75) at 12 cm from the LEDs was used as a light diffuser to provide homogeneous illumination (**Figure 2**). Outside the boxes, electrical circuits helped to control the intensity and the duration of the light stimuli with a 12 V source (**Figure 2**).

An acclimatization acrylic bottle containing the flies to be tested was connected to the vertical arm with a rotating plate (**Figure 2**). Prior to the experiment, flies were counted and separated by sex in groups of 50. After an hour of acclimatization in the acrylic bottle, flies were allowed to move freely for 30 min. After, the flies captured inside each trap were counted to establish the number of flies behaviorally attracted to each LED light source.

The intensity of the lights inside the styrofoam boxes was measured with a radiometer (ILT1400, International Light Technologies) located at the decision point of the two-sided light tunnel. We tested three light intensities. 0.34, 0.15, and 0.034 $\mu W/cm^2$, in the following combinations: white-darkness, blue-darkness, red-darkness, blue-white, blue-red, and white-red. Four replicates of each intensity and combination of lights were tested with *L. sericata* adults.

Statistical analysis

Statistical differences between males and females were determined with a U-Mann Whitney test after evaluating data normality with a Shapiro-Wilk test. Differences in the electrophysiological responses were also compared with a U-Mann Whitney test. Finally, we analyzed the behavioral experiment data with binomial tests and compared the decisions by sex with a Fisher test using SPSS and R software (**R Core Team**, 2013).

Results

Electrophysiological experiments

A typical ERG response obtained after stimulation with light sources in dark-adapted adults of *L. sericata* is shown in **Figure 1**. Independently of the light adaptation or wavelength stimulation, a first phase ("on-response" in **Figure 1B**) was obtained in all cases after a short latency followed by an "off-response" after the stimulus (**Figure 1C**).

The comparison of the spectral curves obtained from males and females under dark conditions or yellow and white selective adaptation showed always the same pattern of responses allowing us to combine the data from individuals of both sexes in each adaptation condition.

After combining the data, the spectral sensitivity of the compound eyes selectively adapted to darkness; white or yellow light conditions showed differences in the normalized responses in some of the wavelengths tested here but, in general, two peaks of response were observed, one at blue (450 nm) with an overlap in the standard deviations of the measurements obtained, and the other at green (510 - 530 nm) with higher normalized responses, especially in those adults tested with an adaptation to darkness.

Interestingly, our experiments with *L. sericata* showed that selective adaptation to white and yellow lights increased the normalized responses to violet lights (400 nm) compared with flies adapted to darkness (**Figure 3**). Additionally, we also found that with yellow and white light selective adaptations, sensitivity to 450 and 900 nm stimuli was higher than for those eyes adapted to darkness (**Figure 3**).

It is worth highlighting that for wavelengths (400, 580, and 600) different from the two main peaks in blue and green lights, all normalized responses were lower than 60%, even in individuals adapted to darkness (**Figure 3**). As expected, the lowest sensitivity was detected near the infrared (900 nm) wavelengths (**Figure 3**).

Dual-choice behavioral experiments

Behavioral experiments testing color lights against dark conditions individually showed that blue, white, and red lights always attracted significantly more *L. sericata* individuals independently of stimuli intensity (**Figure 4**, first three pairs of graphics). The only exception observed was red light facing darkness in males; the lowest intensity tested in those conditions (0.034 µW/cm²) showed no statistically significant differences in the attraction (**Figure 4**). In general, the results of attraction to LED lights with blue, white, and red colors in *L. sericata* individuals of both sexes in Colombia were similar
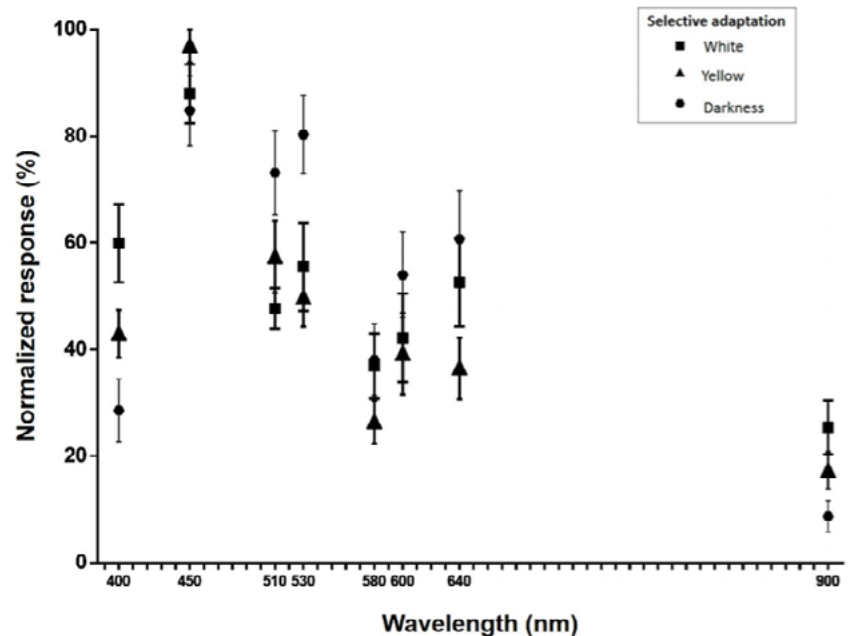

Figure 3. Whole-eye ERG threshold response curves obtained from wild untrained *Lucilia sericata* from Colombia. Values of the normalized "on-response" obtained after stimulation with the different wavelengths tested and with flies adapted to darkness (dots), yellow (triangles), or white (squares) lights.
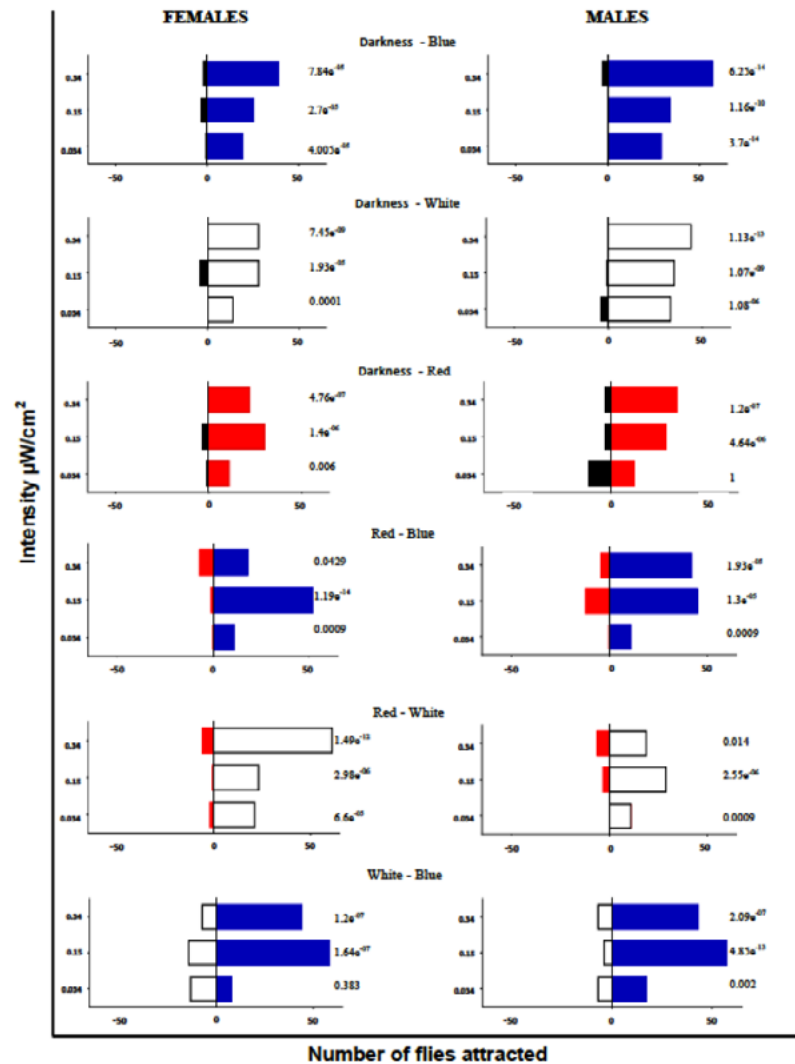
Figure 4. Effect of light colors on the attraction of wild untrained *Lucilia sericata* from Colombia tested in the two-sided light tunnel. Binomial bar charts show the number of females and males attracted after facing lights with different wavelengths (colors of the bars) and intensities (y-axis). p values of the binomial tests are shown to the right of each experiment.

(**Figure 4**). Likewise, when red or white lights were faced against blue LEDs, the blue wavelengths always attracted more individuals regardless of their sexes (**Figure 4**). These results were especially evident with the highest intensities tested (0.34 and 0.15 µW/cm²). However, when the red and white lights competed, it was clear that no matter the intensity, the white lights attracted more individuals than the red wavelengths (**Figure 4**). The results in **figure 4** confirmed the positive phototactic response of *L. sericata* to blue lights followed by white and red lights in that order.

The Fisher test comparing the effect of light intensities on attraction showed differences between sexes, especially at 0.034 µW/cm² intensities in dark vs. red (p = 0.0268) and white vs. blue (p = 0.0007) experiments (**Figure 4**).

Discussion

From an electrophysiological point of view, the waveform of the ERG in *L. sericata* adults from Colombia (**Figure 1**) was similar to those reported for other Diptera like *Musca*

domestica, *Drosophila melanogaster*, *Lucilia caesar*, *Arachnocampa luminosa* and *Calliphora erythrocephala* (**Autrum**, 1950; **Naka & Kuwabara**, 1959; **Yinon**, 1970; **Heisenberg**, 1971; **Kugel**, 1977; **Meyer & Eguchi**, 1984; **Babrekar *et al.***, 2004).

Experiments done with *D. melanogaster* showed that the biphasic response in the ERG originated in the retina and the neuropiles in the optic lobe (**Naka & Kuwabara**, 1959; **Heisenberg**, 1971). Additionally, the biphasic response observed here is charac-teristic of diurnal insects and follows the relation proposed by **Autrum** (1950). For fast-flying insects like flies, an increase in potassium conductance and the ensuing increase in the velocity of photoreceptor response has been demonstrated by **Laughlin & Weckström** (1993). This velocity increase in the responses results in an improvement in the performance of the sensory receptors and a better temporal resolution (**Laughlin & Weckström**, 1993).

Spectral sensitivity of Lucila sericata compound eyes in Colombia

Lucila sericata adults' dark-adapted eyes showed two response peaks, one at blue (450 nm) and the other at green (510 - 530 nm) (**Figure 3**). Both peaks had been previously reported for other insects, including flies (**Kirchner *et al.***, 2005; **van der Kooi *et al.***, 2021).

Selective adaptation of individuals to white light has served to reduce photoreceptor sensitivity to stimulation in all visible light wavelengths and to increase the response of sensory cells to wavelengths outside the visible range. Consequently, this selective adaptation has been used previously to observe the presence of UV receptors in insects (**Kirchner *et al.***, 2005). As expected, our experiments showed that selective adaptation to white and yellow lights produced an increase in the relative response to violet (400 nm) and near-infrared (900 nm) lights in *L. sericata* (**Figure 3**). The lowest values in sensitivity observed at near-infrared wavelengths (**Figure 3**) are explained by insects' inability to detect wavelengths in the infrared range (**van der Kooi *et al.***, 2021), which is why these wavelengths have been used to monitor insect populations under natural conditions (**Rydhmer *et al.***, 2022). Although technical limitations in our experimental setup did not allow us to stimulate with UV lights and, therefore, we were unable to detect the presence of UV receptors, it is expected that stimulation with UV lights should attract *L. sericata* adults, especially if we consider that UV receptors have been previously reported in *L. sericata* (**McCann & Arnett**, 1972) and other Diptera (**Allan *et al.***, 1987; **Briscoe & Chittka**, 2001; **Diclaro *et al.***, 2012; **van der Kooi *et al.***, 2021) and that behavioral experiments in other *L. sericata* populations have shown attraction to these wavelengths (**Brodie *et al.***, 2015).

On the other hand, selective adaptation to yellow wavelengths has shown reduced responses below 500 nm (**Kirchner *et al.***, 2005). In our experiments, the selective adaptation to yellow lights allowed us to detect responses to a peak in the blue-violet range in *L. sericata* (**Figure 3**).

Using electrophysiological studies, we confirmed the presence of two photoreceptors, one for blue (450 nm) and the other for green (510-530 nm) in *L. sericata* from Colombia. The sensitivity observed in the violet range (400 nm) after selective adaptation experiments (**Figure 3**) and the results obtained previously for *L. sericata* and other insects (**McCann & Arnett**, 1972; **Allan *et al.***, 1987; **Briscoe & Chittka**, 2001; **Diclaro *et al.***, 2012; **Lunau**, 2014; **McFadden & Hans**, 2019; **van der Kooi *et al.***, 2021; **López-Reyes *et al.***, 2022; **McNeill *et al.***, 2016; **Ortiz *et al.***, 2023) suggest that in Colombia, *L. sericata* adults' compound eyes would have trichromacy.

Besides, the ranges of sensitivity measured for *L. sericata* adults from Colombia are similar to those reported for other populations (**McFadden & Hans**, 2019) and also for other diurnal and nocturnal insects with the presence of receptors to blue, green, and UV, like *Euglossa dilemma* (**Dexheimer *et al.***, 2023), *Rhodnius prolixus* (**Ortiz *et al.***, 2023), *Myzus persicae* (**Kirchner *et al.***, 2005), *Glossina* sp (**Steverding & Troscianko**, 2004) and *Arachnocampa luminosa* (**Meyer & Eguchi**, 1984).

Two-sided light tunnel behavioral responses in Lucila sericata from Colombia

Behavioral responses showed by *L. sericata* in the two-sided light tunnel confirmed the main electrophysiological results mentioned above. Untrained adults faced against darkness vs. lights of different wavelengths were always attracted by the lights, independently of the wavelength (**Figure 4**).

We found no behavioral differences between males and females regarding their attraction to LED lights with different wavelengths and intensities (**Figure 4**), which we expected, especially bearing in mind that only a few flies possess sexually dimorphic structures that are only visually displayed during courtship (**Lunau**, 2014). If we set aside the importance of colors during courtship and mating in flies and try to focus on other ecological roles of color vision: foraging, feeding, or navigation to find shelter, we should delve into the variability of visual environments and fly species' different sensory systems.

In our experiments we found that blue lights were the most attractive for flies; however, behavioral experiments done in other *L. sericata* populations testing additional wavelengths in UV emissions or reflecting on objects have shown that yellow or purple lights are more attractive than blue light stimuli (**Brodie *et al.***, 2015; **McFadden & Hans**, 2019). Although we never tested UV, yellow, or even purple lights behaviorally, our electrophysiological results with purple lights predict sensitivity to lower wavelengths, suggesting the possibility of UV detection even (**Figure 3**).

However, when lights at different wavelengths were faced, attraction to blue and white lights was always stronger (**Figure 4**). These responses can be explained because the white and blue LEDs used in the experiments (**Table 1**) presented mainly emission peaks in the wavelengths where *L. sericata* showed the highest spectral sensitivity (450-530 nm) (**Figure 3**).

In some behavioral studies with Diptera and Hymenoptera, attraction to blue lights has also been highlighted (**Zablocka**, 1972; **Fukushi**, 1989; **Cilek**, 2003; **Steverding & Troscianko**, 2004; **Geden**, 2006; **Diclaro *et al.***, 2012; **Hsua & Cheng**, 2012). However, in beetles and other *L. sericata* populations, the attraction to LED lights in the yellow (585 nm) and green (570 nm) is higher compared with blue (472 nm) or white (420-775 nm) (**Otálora-Luna & Dickens**, 2010; **Brodie *et al.***, 2015). These results underline the importance of testing color preferences in different orders of insects without extrapolating results from one order to the others.

In **figure 4**, we can also observe an attraction to red wavelengths (640 nm). Intracellular experiments have shown that these wavelengths are outside *L. sericata*'s range of detection (**McCann & Arnett**, 1972). However, our ERG results showed that the relative response of sensitivity to red stimulation ranged between 40% and 60% (**Figure 3**). Such relative response of the photoreceptors measured in our ERGs may explain the behavioral attraction to red LEDs in our and other behavioral experiments (**Brodie *et al.***, 2015). Attraction to red lights has been reported in other insects even without electrophysiological evidence of photoreceptors in that range of wavelengths (**Allan *et al.***, 1987).

Lucila sericata and its visual interaction with diurnal natural environments

Diurnal natural environments are very complex, always changing with heterogeneous visual signals from the reflectance spectrum, the forest geometry, the weather, the time of the day, and the ambient light (**Endler**, 1993). Thus, direct (light of the sun) and diffuse (light reflected from all other natural sources) lights include white, blue, green, and infrared wavelengths (**Endler**, 1993).

In flies and plants ecological interactions, flies have been frequently observed visiting yellow (*Eristalis tenax* or *Episyrphus balteatus*) or white flowers, as well as blue (*Rhingia campestris*, *Volucella bombylans* or *Bombylius fuliginosus*) and red floral colors (**Lunau**, 2014). Flower colors also affect flies' landing, proboscis extension, and oviposition (**Lunau**, 2014). Attraction to plant inflorescences with a mixture of yellow and white colors to obtain nutrients and facilitate their ovary maturation has also been observed in *L. sericata* (**Brodie *et al.***, 2015).

However, since *L. sericata* has a reduced capacity to fly in darkness (**Wooldridge *et al.***, 2007) and is rarely found indoors or in the forest during day hours (**Smith *et al.***, 2002), and it is commonly found infesting carrion in open pasture environments, it is clear that the high attraction observed here to blue emissions responds to the detection of shadow areas that are important as resting places to hide between leaves and natural objects reflecting yellow and green wavelengths at different intensities (**Steverding & Troscianko**, 2004; **Kelver & Osorio**, 2010; **Artamonov**, 2012). Under natural conditions, *L. sericata* adults have been found to be attracted significantly to black, blue, white, green, and yellow stimuli (**Wall *et al.***, 1992; **Hall *et al.***, 1995; **Wall & Smith**, 1996; **Brodie *et al.***, 2015), probably used as a source of information on additional food supplies (**Lunau**, 2014).

Flies are well known to be largely visually oriented animals (**Lunau**, 2014). In the case of *L. sericata*, the importance of this feature for mate-seeking under natural direct light conditions and reflected light flashes with blue and green spectral components has been shown when flies are wing beating at 178 Hz, which adds to the absence of mate-seeking behaviors on cloudy days when these light flashes are absent (**Eichorn *et al.***, 2017). Again, to detect these flashes, the presence of the blue and green peaks reported in our electrophysiological experiments in *L. sericata*'s compound eyes (**Figure 3**) is very important to explain the behaviors observed under natural conditions.

Worldwide, traps to capture *Lucilia* species have been developed by using synthetic odor baits to attract and capture flies (**Hutchinson**, 2000; **Hall *et al.***, 2003) and reduce damage to the industry (**Urech *et al.***, 2009). Although traps with synthetic attractants are recommended to control flies' populations, their ecological value as a strategy in entomological surveillance or adult collection to breed populations under laboratory conditions is in doubt. This highlights the utility of our results regarding LED lights with different colors to develop light traps or to improve pan traps (**Shrestha *et al.***, 2019) that, together with citizen science (**Barahona-Segovia & Barcelo**, 2021), can be used in the surveillance of Colombian *L. sericata* and other flies populations to track their presence and abundance in different ecosystems. We require more physiological studies in Colombian insect populations to develop better and more efficient traps for different purposes.

Acknowledgments

Conflicts interests

The authors declare no conflicts of interest.

Authors´contributions

AGC: Project approach, methodology design, experiments, results analysis, and preparation of the manuscript. JM: Project approach, methodology design, and preparation of the manuscript. Both authors read and approved the final version of the manuscript.

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