Short Communication

Effect of Luminance on Visual Performance by Secondary Cavity and Non-Cavity Nesting Passerines

Nehafta Bibi1,2, Faiq Jan3, Munawar Saleem Ahmad4 and Haitao Wang1,5,*
1Jilin Engineering Laboratory for Avian Ecology and Conservation Genetics, School of Life Sciences, Northeast Normal University, Changchun, China
2Government Girls Degree College, Mansehra 21300, Khyber Pakhtunkhwa, Pakistan
3Government Postgraduate College, Nowshera 24100, Khyber Pakhtunkhwa, Pakistan
4Department of Zoology, University of Swabi, Swabi 23340, Khyber Pakhtunkhwa
5Jilin Key Laboratory of Animal Resource Conservation and Utilization, Northeast Normal University, 5268 Renmim Street, Changchun, China

ABSTRACT

The great majority of avian species is diurnal and thus endures variation in light intensities, associated with daily, seasonal or lunar cycles. These diurnal birds search their food in light abundant environment and raise their broods in dark cavities. However their visual performance in dim light conditions is largely unknown. Here, we compared light intensity threshold of activity in two groups of passerines, i.e. secondary cavity and non-cavity nesting. For this purpose, different species of secondary cavity and non-cavity nesting passerines were subjected to two phases of trials: in the first trial birds were released in an experimental cage and allowed them to accommodate themselves in darkness for 10 min. In the second trial we turned on the dimmer to a given luminance for 2 min. We found that activity threshold for secondary cavity nesting passerines ranged from 0.05 to 0.2 cdm$^{-2}$ and non-cavity nesting passerines from 22.00 to 16.00 cdm$^{-2}$. Our results shed light on the question about potential effect of luminance on visual performance by secondary cavity and non-cavity nesting passerines.

Light has an enormous influence on several aspects of bird biology, ecology and physiology (Oishi et al., 2001). In birds, the eyes, pineal organ and hypothalamus regulate circadian rhythms and photoperiodism (Oishi et al., 2001). Likewise, the duration of singing, development of reproductive system, level of testosterone, and molting in male birds are largely influenced by period of illumination (Dominoni et al., 2013). Intensity of light differs from low light conditions to brighter sunny days. Several diurnal bird species can be active in low light conditions and forage in lightless conditions (Gomez et al., 2014). It is evident that avian species may be highly dependent upon vision, and vision is used to control many behaviors (Martin et al., 2004). Generally, birds depend heavily on vision and particularly on color; however, it remains unknown if any avian species has a multifocal optical network or not (Lind et al., 2008). Majority of diurnal birds have circular pupils and relatively high minimum f-numbers with little exception e.g. owls (Lind et al., 2008). The avian eyes have two main refractive elements; the cornea and the lens are separated by an aperture. This basic concept embodies a number of degrees of freedom, which are capable of generating a variety of visual performance (Martin and Osorio, 2008).

Most species of birds use rods for brightness detection under low light conditions and cones for color vision (Podkowa et al., 2019). However, it has been documented in previous studies that the tendency to encounter with this rapidly fluctuating level of light has evolved only in cavity nesters (Zhang et al., 2019; Larsen et al., 2020). Several former studies investigated that globally over 1700 and in Australia over 300 avian species use tree cavities (van der Hoek et al., 2017).

Several former studies investigated that many avian species either can orient or forage in lightless conditions by touch and/or sensory information (Corfield et al., 2015). Some of the avian species though develop invariably particular behavioral, physiological and anatomical adaptations, allowing them to effectively use these senses in the lightless conditions (Dominoni et al., 2020). The cave-dwelling species like oilbird (Steatornis...
birds can either see and work under low light conditions, or understanding animal communication. Several species of avian vision, which offers essential information for (Martin et al., 2014). However, there is no known use of specific sensory adaptations in cavity nesters and these birds are likely to rely on vision to direct their behavior within their dark cavities. This is supported by the variability in parent feeding behavior in response to manipulation of chick mouth flanges brightness and color (Wiebe and Slagsvold, 2009). When cavity nesters do not use their vision to work in total darkness, there must be a certain illumination limit beyond which sensing is difficult, as nest cavities are very dark to use (Land and Nilsson, 2002). There are therefore reasons to expect that light conditions inside dark cavities may limit both the selection of nesting sites and the evolution of nesting habit in cavity nesters (Wesołowski and Maziarz, 2012). There are however restricted data on light conditions within cavities. To provide more information on luminance, in the present study we compared light intensity threshold of activity i.e., movement or foraging in two groups of passerines i.e., secondary and non-cavity nesting. Secondly, we also measured the feeding latency between two groups of birds.

Materials and methods

In this study, secondary and non-cavity nesting birds were caught with trapping cages in Jilin city and the adjacent areas in Jilin Province, China, between May and June 2016 and January and February 2017. We used 7 adult birds of each selected species. Secondary cavity nesting birds included great tit (Parus major) and sparrow (Passer domesticus), and non-cavity nesting birds included red-billed leiothrix (Leithrix lutea) and Eurasian siskin (Spinus spinus). Within 4 h individuals of these species from various populations were transported to the laboratory. On arrival at the research facility, individuals were housed in 0.9 m×0.4 m×0.5 m cages under a 12:12 h photoperiod, each with side and back walls, compact upper and lower surfaces, wire netting and three small perches (Bibi et al., 2019). The worms, commercial seed mixtures, sunflower seeds and water were provided to the birds ad libitum. Sex of all the birds was determined following Svensson (1992). Exposure to humans was minimized, and the individuals were left undisturbed overnight. The individuals were released back to their natural habitat after completion of the experiment.

Individuals were placed in a light safe testing room, with walls covered with black curtain (H×L×W: 4.0×2.4×2.3 m) (Dingemanse et al., 2002). We placed two feeders in the experimental cage and monitored bird’s activity with two cameras in the side walls. The two groups of birds were trained to hunt for prey in the experimental cage at varying luminance level 0-22 cd/m² until they reached a constant latency to search and capture rate. Each test contained two blocks. In the first block, we released the birds in the experimental cage and allowed them to accommodate darkness for 10 min, then turned on the dimmer to a given luminance for 2 min and observed whether the test bird foraged or moved to engage in other activities and then the trial was terminated. Birds were trained according to the Lind and Kelber (2009) protocol for parrots (Gomez et al., 2014). A white paper placed horizontally just below the feeders and a luminance meter (LMT 1009) were used to calculate the luminance. Luminance meter (LMT 1009) has an angular field 3°, 1°, 20°, 6° selectable. Photometer head with Si-photodetector, fine V (lambda)-approximation. It could measure distance approx. 0.50 m to infinity. During the trial we switched on the dimmer, a single detector on the luminance meter detected and measured the brightness displayed on the screen. We also recorded the readings for further use. When evaluating the light sources, we can calculate the luminance or illuminance of the source. Luminance (L) is also referred to as brightness of light source and measured in candela per square meter (cd/m²). Illuminance (E) is the volume of light on a surface per unit, expressed in lux or lumen per unit meter², lm/m². The third unit of light is luminous intensity (I) which is amount of light radiating in a specific direction. It expresses itself in candela (cd). However, amount sum of light emitted by light source is denoted as luminous flux (LM). It is measured in lumens (lm).

During trial, only worms were provided to testing individual to increase their desire to feed the feeders.

Individuals were first trained at varying luminance levels. Individuals were considered as efficiently trained when they started using feeders in one trial out of two at given luminance resulting to P = 0.05 (two tailed binomial test) (Gomez et al., 2014). We then continued testing from decreased luminance to maximum point. Upon acclimatization for at least 10 min, individuals were presented with one feeder and we observed whether the test bird foraged or moved to engage in other activities and
then the trial was terminated. Feeding latency and light intensity were recorded, however maximum latency was given to the birds that did not move or forage. After the trial, testing individuals were taken back to their aviary before release (Gomez et al., 2014).

Comparison between the secondary and non-cavity nesting birds were made using the independent sample t-test. Difference in feeding latency between secondary and non-cavity nesting birds were calculated using generalized linear model. Individual identity was used as random factor and trial as fixed factor. We checked data for normality, and transformed variables to meet the assumptions of generalized linear model (GLM). All tests were two tailed and alpha level was set at 0.05. All data were analyzed in SPSS (V. 20 IBM). Descriptive statistics with the first and third quartiles (Q25–75%) were viewed as a mean ± standard deviation or as a median (Me) (Fernández-Juricic et al., 2007).

In this study intensity threshold of vision was tested between two groups of passerines. In our study range of luminance in secondary cavity nesting passerines is comparable to the similar values of about 0.4 and 0.1 cdm−2 which have been reported in budgerigars Melopsittacus undulatus and Bourke’s parrots Neopsephotusbourkii (Lind and Kelber, 2009). Similarly, our results for secondary cavity nesting passerines are also comparable with Wesołowski and Maziarz (2012) for marsh tits Poecile palustris and great tits Parus major, where they reported the same figure of the range of luminance threshold (0.05 to 0.2 cdm−2). Our study is also comparable with Podkowa and Surmacki (2017), where light in open nesting species like great tits Parus major was shown to be less important due to higher overall illumination compared to secondary cavity nesting birds constructing deeper nests.

Interestingly, several previous studies investigated chick coloration in cavities or egg in Parus species described variation in parental behavior manipulated a reflectance over a broad variety of wave lengths or UV ranges (Wiebe and Slagsvold, 2009; Dugas, 2009; Antonov et al., 2011). These earlier investigations did not, however, determine which indications were used, except in one case where birds might use brightness (Antonov et al., 2011).

As these cavity nesting birds have additional issues to address i.e. their optical system adapts to rapidly fluctuating light rates, aside from the need to be able to see in low light conditions (Cassey, 2009). Apparently, these cavity nesting birds can adapt even to fluctuating light levels, but it remains uncertain how do they do that? Certain mechanism and function of highly dynamic pupil may be involved (Lind and Kelber, 2009). Like other vertebrates, the process of dark full adaptation is relatively low also in bird’s eyes, taking up to 40 min (Reynolds et al., 2009). It might also be possible that vision of these cavity nesters is not well adapted to the luminance level within cavities or they employ some additional but unexplained light/dark adaptation mechanisms. A detailed investigation to highlight and uncover these mechanisms will definitely be worthwhile.

In summary, the current research has shown that the
tree cavities may be really dark spots and open nesting places have higher luminance but, both secondary and non-cavity nesting birds must be able to see in low light only under certain threshold. However, for cavity nesters tending broods within the dark cavities may be possible with sustainably poorer spatial resolution relative to local foraging. Our analysis also shows that under certain natural conditions of illumination, enough light availability would be unlikely in the cavities to make vision of birds while non-cavity nesters possess a greater luminance. It means that using cavities by cavity nesters possess real sensory challenges. Therefore, we propose that it would be very instructive to record these measurements with different species; living in contrasting environments.

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Statement of conflict of interest

The authors have declared no competing interests.

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