Behavioural Brain Research 296 (2016) 233–239

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr

Research report

Annual life-history dependent seasonal differences in neural activity of the olfactory system between non-migratory and migratory songbirds

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HIGHLIGHTS

- Compares seasonal change in neural activity of olfactory system in songbirds.
- Seasonal ZENK activation differs between non-migratory and migratory birds.
- Birds during the post-breeding state have highest ZENK activation.
- Seasonal plasticity in neural activity was linked with annual life-history states.
- Results possibly invoke adaptive differences in neural activity of sensory systems.

ARTICLE INFO

Article history:
Received 30 April 2015
Received in revised form 9 September 2015
Accepted 14 September 2015
Available online 16 September 2015

Keywords:
Indian weaver bird
Olfaction
Redheaded bunting
Songbirds
ZENK

ABSTRACT

Present study investigated seasonal plasticity in neural activity of the olfactory system, and assessed whether this was influenced by differences in seasonal life-history states (LHSs) between the non-migratory and migratory birds. Brains of non-migratory Indian weaver birds and migratory redheaded buntings were processed for ZENK immunohistochemistry, a marker of neuronal activation, at the times of equinoxes (March, September) and solstices (June, December), which correspond with the periods of different seasonal LHSs during the year. Immunoreactivity was quantified in brain regions comprising the olfactory system viz. olfactory bulb (OB), anterior olfactory nucleus (AON), prepiriform cortex (CPP), lateral olfactory tract (LOT) and olfactory cortex (piriform cortex, CPI; lateral olfactory cortex, LOC). In weaver birds, ZENK-like immunoreactive (ZENK-lir) cells were significantly higher in all the brain areas during post-breeding season (September) than during the other seasons; OBs had higher neuronal activity in the breeding season (June), however. A similar neural activity pattern but at enhanced levels was found in migratory buntings almost all the year. These results for the first time show LHS-associated differences in the seasonal plasticity of a sensory system between the non-migratory and migratory songbirds.

1. Introduction

Songbirds show great dependence on olfactory cues, comparable to that of mammals [1–3]. They use olfaction in performing their diverse daily and seasonal tasks, including the foraging [4], prey detection [5], predator avoidance [6], navigation [7], nest material identification and recognition [8,9], social behavior [10] and colony and kin recognitions [11,12]. In a mate choice experiment, the spotless starlings (*Sturnus unicolor*) have been found using chemical cues in sex discrimination of their conspecifics [13]. Also, differences in the uropygial oil-gland chemistry correlate with seasonal changes in the male sexual behavior in female domestic ducks, *Anas platyrhynchos*, and chicken, *Gallus domesticus* [14,15]. Further, migratory songbirds use olfactory cues for the orientation and navigational purposes during their long trans-continental flights. Deprived olfactory perception results in the decay of migratory orientation in anosmic catbirds, *Dumetella carolinensis* [16] as well as

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http://dx.doi.org/10.1016/j.bbr.2015.09.019
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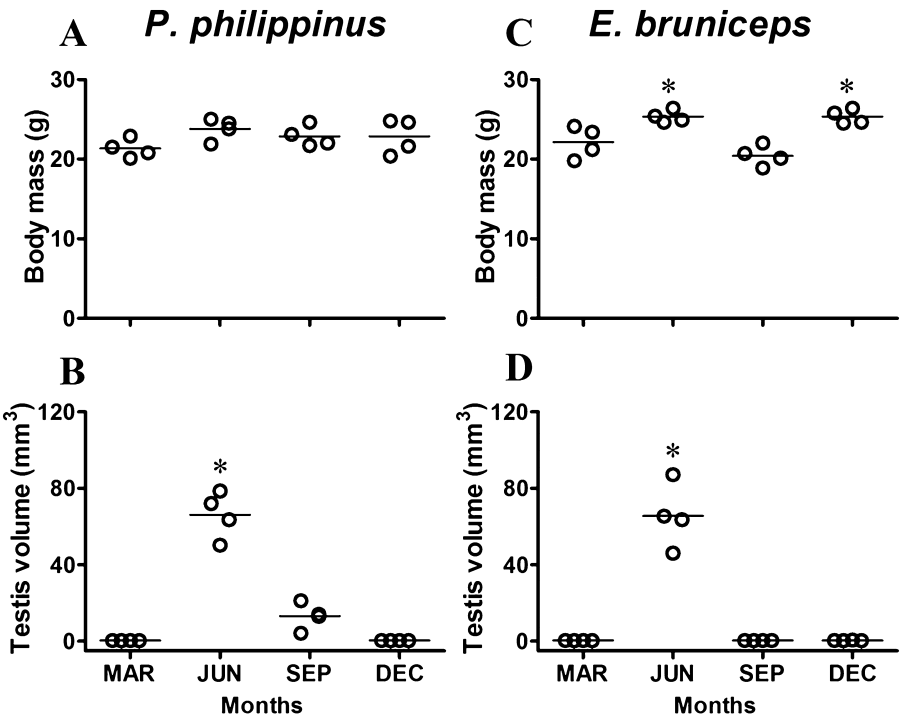

Fig. 1. Changes in body mass (A and C) and testis size (B and D) in Indian weaver birds (*Ploceus philippinus*; A and B) and redheaded buntings (*Emberiza bruniceps*; C and D) during four months of the year. Each symbol represents an individual bird and a horizontal line in the graph indicates the mean value. Asterisk (*) indicates the significant difference between groups ($p < 0.05$; Newman–Keuls post-hoc test).

the homeward navigation in migratory European starlings, *Sturnus vulgaris* [17] and swifts, *Apus apus* [18].

The sensitivity of the olfactory system can change with the seasonal life-history states, LHSs. For example, the olfactory bulbs (OBs) loose ability of detecting natural odors emanating from the green plant nest materials, independent of the testosterone levels, in male European starlings [19]. However, the neural basis of seasonal differences in odor discrimination ability has not been

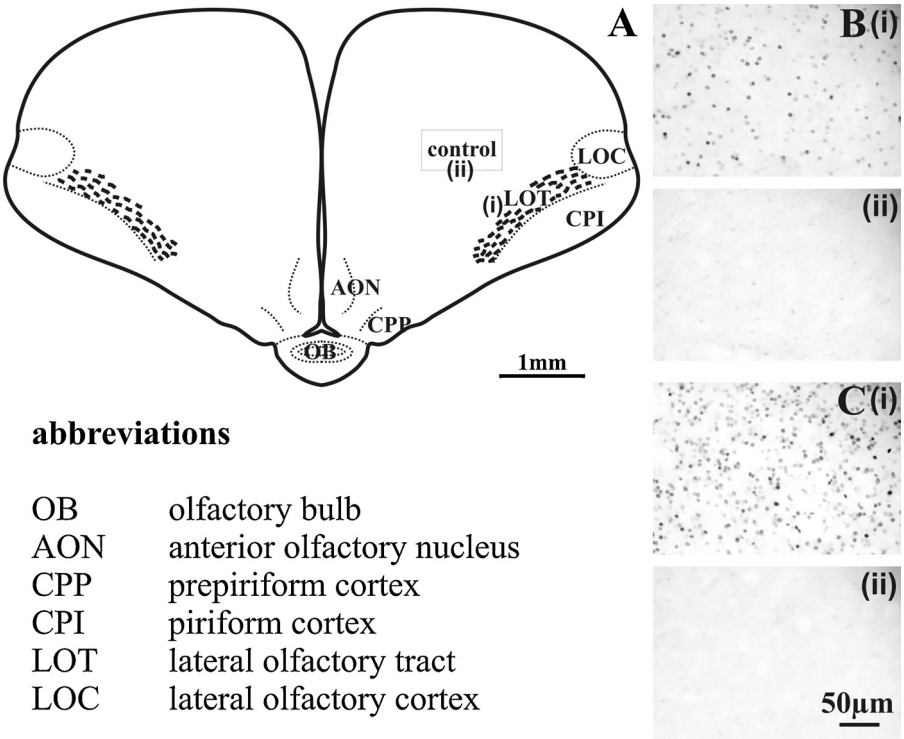

Fig. 2. (A) Schematic drawing of the coronal section of a songbird brain, with an approximate anatomical position of different nuclei (OB, AON, CPP, CPI, LOT and LOC) constituting the olfactory system, along with a region outside the olfactory system (control) shown in the left hemisphere of the brain, where ZENK-immunoreactivity was measured. Scale bar = 1 mm. (B and C) Panel of photomicrographs (using 40× objective) of LOT (i) and control region (ii) from the brain of Indian weaver bird (*Ploceus philippinus*; B) and redheaded bunting (*Emberiza bruniceps*; C). Scale bar = 50 µm.