VOLUMETRIC ANALYSIS OF THE VISUAL, TRIGEMINAL AND ACOUSTIC NUCLEI IN FOUR AVIAN SPECIES (RHEIDAE, SPHENISCIDAE, TINAMIDAE)

N. BEE DE SPERONI & F. CAREZZANO

Departamento de Diversidad Biológica y Ecología, Universidad Nacional de Córdoba, Vélez Sarsfield 299, 5000 Córdoba, Argentina

Received 22 September 1993, accepted 6 June 1994

SUMMARY

BEE DE SPERONI, N. & F. CAREZZANO. 1995 Volumetric analysis of the vi/sual, trigeminal and acoustic nuclei in four avian species (Rheidae, Spheniscidae, Tinamidae). *Marine Ornithology* 23: 11-15.

The volumetric composition of the tectofugal, trigeminal and auditory nuclei were determined in four avian species: Greater Rhea *Rhea americana*, Magellanic Penguin *Spheniscus magellanicus*, Tataupa Tinamou *Crypturellus tataupa* and Redwinged Tinamou *Rhynchotus rufescens*. The Tataupa and Redwinged Tinamous have well-developed nuclei of the tectofugal pathways. The Magellanic Penguin shows low volumetric values for auditory nuclei. Trigeminal nuclei are relatively larger in Redwinged and Tataupa Tinamous than in both the Rhea and the Magellanic Penguin.

INTRODUCTION

Previous studies members of the Rheidae, Spheniscidae and Tinamidae has been carried out by Bee de Speroni & Pirlot (1987) and by Bee de Speroni & Carezzano (in press), but without analyzing the relative size of the nuclei of the main sensory pathways. Although these families have the common characteristic of being mediocre flyers (Tinamidae) or flightless (Rheidae and Spheniscidae), they have important eco-ethological differences in their encephalic organization.

The purpose of this study is to establish quantitative differences of the nuclei of visual, trigeminal, and acoustical pathways between different avian species of the Neotropical avian fauna.

MATERIALS AND METHODS

One brain of each of the following was used: one male Greater Rhea with a body mass of 25 kg and a brain mass of 19.9 g; a female Tataupa Tinamou with a body mass is of 225 g and brain mass of 1.64 g; a male Redwinged Tinamou with a body mass of 850 g and brain mass of 3.67 g; and a female Magellanic Penguin with a body mass of 3.3 kg and brain mass of 17.3 g.

The birds were perfused with formalin (one part formaldehyde, seven parts water), and their brains we embedded in paraffin and sectioned at 10 um for Tataupa and Redwinged Tinamous and 15 um for Greater Rhea and Magellanic Penguin. The sections were stained with cresyl violet to aid the identification of structures.

The structures considered were E, *ectostriatum*; MLd, *nucleus mesencephalicus lateralis pars dorsalis*; NBP, *nucleus basalis prosencephali*; PrV, *nucleus sensorius principalis nervi trigemini*; Ov, *nucleus ovoidalis*; Rt, *nucleus rotundus* (including *nucleus triangularis* because it is close to Rt and is difficult to identify) ; and TO, *tectum opticum*.

The volume of each structure was estimated using a volumetric method previously described by Stephan *et al.* (1981). We had only four individual birds at our disposal and are aware that such a small sample is not satisfactory for a conventional statistical approach. This situation has been experienced in many studies of relative brain size in vertebrates, especially in mammals, by a number of authors. It is due to the fact that the work, time and expense involved in preparing complete serial sections of brains, as well as the scarcity of such materials, precludes using large samples. This problem in methodology is reviewed by Pirlot (1987). Studies are restricted to relatively high and widely separated taxonomic units and do not require exact testing of mean differences and variances.

RESULTS AND DISCUSSION

The comparisons in percentage of nuclei and telencephalic components of the visual, trigeminal and acoustic pathways are summarized in Table 1.

Tectofugal visual pathways

The highest volumes of the TO, Rt and E were seen in the Tataupa Tinamou (TO=10.06%, Rt=0.47% and E=1.48%), followed by the Redwinged Tinamou (TO=8.27%, Rt=0.39% and E=1.41%) and Greater Rhea (TO=6.63%, Rt=0.26% and E=1.01%), whereas lowest values were shown by the Magellanic Penguin (TO=3.84%, Rt=0.15%, and E=0.90%).

Güntürkün (1991) described three visual pathways in the pigeon: the thalamofugal and first and second tectofugal pathways. The first tectofugal pathway is homologous to the retino-colliculo-pulvino-extrastriatal tract of mammals (Karten & Hodos 1970). The superficial layers of the TO receive a topographic representation of the contra lateral retina (Hunt & Webster 1975) while the inner layers receive somatokinetic and acoustic information (Knudsen & Knudsen 1983). The cells of this layer are the origins of motor and visual efferents that project to the *nucleus rotundus* (Rt). The Rt sends fibres to the ipsilateral *ectostriatum* (Karten & Hodos 1970, Benowitz & Karten 1976). The tectal projections innervate both the Rt, and the *nucleus dorsalis posterior thalami* (DLP). The DLP projects to the *neostriatum intermedium* and the *neostriatum caudale* (Güntürkün 1991).

The thalamofugal pathway is similar to the geniculo-striatal visual pathway of mammals (Karten *et al.* 1973). The retinal ganglion cells project to the tectum opticum and to a complex of nuclei in the dorsolateral thalamus, which in turn innervates the ipsilateral and contralateral visual Wulst in the forebrain. This complex of nuclei is collectively called the *nucleus opticus principalis thalami* (Karten *et al.* 1973, Miceli *et al.* 1975).

Currently we are analyzing the nuclei of the thalamofugal and second tectofugal pathways in these four species of birds.

Acoustic pathway

The acoustic pathway originates from the cochlea and projects to the myelencephalon (Boord 1968). The efferents of the myelencephalic nuclei form the lateral lemniscus which terminates in MLd (Karten 1974). The projections of MLd innervate the Ov of the thalamus, which in turn projects to field L (Rose) of the telencephalon (Bonke *et al.* 1979). MLd is related to acoustic localization (Kundsen & Kundsen 1983), whereas both the Ov and the field L (Rose) are involved in the discrimination and learning of complex acoustic

TABLE 1

PERCENTAGE COMPARISONS OF NUCLEI AND TELENCEPHALIC STRUCTURES OF THE VISUALS, ACOUSTIC AND TRIGEMINAL PATHWAYS OF GREATER RHEA, TATAUPA TINAMOU, REDWINGED TINAMOU AND MAGELLANIC PENGUIN (PERCENTAGES WITH RESPECT AT VOLUME OF THE TOTAL BRAIN)

	Greater Rhea	Tataupa Tinamou	Redwinged Tinamou	Magellanic Penguin
		Tectofugal		
TO	6.63%*	10.06%*	8.27%**	3.84%*
Rt	0.26%	0.47%	0.39%	0.15%
E	1.01%	1.48%	1.41%	0.90%
		Acoustic		
MLd	0.20%	0.39%	0.30%	0.06%
Ov	0.03%	0.07%	0.03%	0.01%
		Trigeminal		
PrV	0.02%	0.04%	0.05%	0.02%
NBP	0.28%	0.39%	0.41%	0.29%

Abreviations: E, ectostriatum; MLd, nucleus mesencephalicus lateralis pars dorsalis; NBP, nucleus basalis prosencephali; PrV, nucleus sensorius principalis nervi trigemini; Ov, nucleus ovoidalis; Rt, nucleus rotundus (include nucleus triangularis); TO, tectum opticum.

* From Bee de Speroni & Pirlot (1987).

** From Bee de Speroni & Carezzano (in press).

patterns (motives) like the specific vocalization of different species (Langer *et al.* 1981).

In the Tataupa Tinamou MLd and Ov have the highest volume (0.39% and 0.07%, respectively), the Magellanic Penguin has the lowest values (0.06% and 0.01%, respectively). The Greater Rhea and Redwinged Tinamou have similar relative sizes of Ov (0.03%), but not MLd, which is higher in Redwinged Tinamou (Redwinged Tinamou 0.30% and Greater Rhea 0.20%).

The tinamids have a wide vocalization repertoire used during courtship, or to alert offspring or when frightened (Bee de Speroni & Carezzano in press). The offspring of the Greater Rhea are profuse vocalists, whose parents detect predators not only by sight but also through hearing.

Trigeminal or quinto-frontal pathway

PrV and NBP have similar volumes in Greater Rhea and Magellanic Penguin (0.02%, 0.28% and 0.02%, 0.29%, respectively), lowest to both Redwinged Tinamou and Tataupa Tinamou (0.05%, 0.41% and 0.04% and 0.39% respectively).

The PrV receives the information of the tactile receptors of the bill and the oral cavity (Dubbeldam & Karten 1978). The efferents of the PrV found in the diencephalon and in the NBP constitute the trigeminal or quinto-frontal pathway (Wild *et al.* 1985). This pathway is implicated in the control of pecking, food intake (Schall & Deluis 1986) and in tactile examination of the preys (Gerristen & Meiboom 1986).

The efferences of NBP are situated in the frontal Nst (Schall *et al.* 1986), partly terminating in the *archistriatum* via the *tractus frontoarchistriatalis* (Wild *et al.* 1985). The efferents of the dorsal and anterior portion of the *archistriatum* reach diverse myelencephalic components which innervate the mandibular musculature (Zecha 1962, Zeier & Karten 1971, Wild & Zeigler 1980, Berkhoudt *et al.* 1982).

CONCLUSIONS

The highest volumes of the TO, Rt and E were seen in the two species of tinamids, whereas lowest values were showed by the Magellanic Penguin. MLd and Ov have the largest volume in the Tataupa Tinamou, whereas the lowest values are observed in the Magellanic Penguin. Greater Rhea and Redwinged Tinamou show similar relative sizes of Ov, but not MLd, which is larger in the Redwinged Tinamou. PrV and NBP have similar volumes in both the Greater Rhea and Magellanic Penguin, which are substantially lower than the that of the Redwinged Tinamou or the Tataupa Tinamou.

ACKNOWLEDGEMENTS

The authors wish to thank the Director and staff of the Centro Patagónico, Puerto Madryn, Argentina and The Jardín Zoológico de Santiago del Estero, Argentina for their help in collecting the material.

REFERENCES

BEE DE SPERONI, N. & CAREZZANO, F. In press. Estudio cuantitativo de componentes encefálicos en tres especies de tinámidos, con un enfoque ecoetológico (Aves: Tinamidae). *Rev. Fac. Ciencias Méd. Córdoba.*

BEE DE SPERONI, N. & PIRLOT, P. 1987. Relative size of avian brain components of the Magellanic Penguin, the Greater Rhea and the Tataupa Tinamou. *Cormorant* 15: 7-22.

BENOWITZ, L. I. & KARTEN, H. J. 1976. Organization of the tectofugal visual pathways in the pigeon: a retrograde transport study. *J. Comp. Neurol.* 167: 503-520.

BERKHOUDT, H., KLEIN, B.G. & ZEIGLER, H.P. 1982. Afferents to the trigeminal and facial motor nuclei in pigeon (*Columba livia* L.): central connections of jaw motoneurons. *J. Comp. Neurol.* 209: 301-312.

BONKE, B.A., BONKE, H. & SCHEICH, H. 1979. Connectivity of the auditory forebrain nuclei in the guinea fowl (*Numida meleagris*). *Cell Tiss. Res.* 200: 101-121.

BOORD, R.L. 1968.Ascending projections of primary cochlear nuclei and nucleus laminaris in pigeon. *J. Comp. Neurol.* 133: 535-542.

DUBBELDAM, J.L. & KARTEN, H.J. 1978. The trigeminal system in the pigeon (*Columba livia*). I. Projections of the Gasserian ganglion. *J. Comp. Neurol.* 180: 661-678.

GERRISTEN, A.F.C. & MEIBOOM, A. 1986. The role of touch in prey density estimation by *Calidris alba*. *Netherlands J. Zool.* 36: 530-562.

GÜNTÜRKÜN, O. 1991. The functional organization of the avian visual system. In: ANDREW, R. J. (Ed.). Neural and behavioural plasticity: the use of the domestic chick as a model. Oxford: Oxford University Press. pp. 92-105.

HUNT, S.P. & WEBSTER, K.E. 1975. The projections of the retina upon the optic tectum of the pigeon. *J. Comp. Neurol.* 162: 433-466.

KARTEN, H.J. 1974. The structural organization of the avian brain: an overview. In: GOODMAN, I.J. & SCHEIN, M.W. (Eds). Birds, brain and behavior. New York: Academic Press. pp. 29-73.

KARTEN, H.J. & HODOS, W. 1970. Telencephalic projections of the nucleus rotundus in the pigeon (*Columba livia*). *J. Comp. Neurol.* 140: 35-52.

KARTEN, H.J., HODOS, W., NAUTA, W.J.H. & REVZIN, A.M. 1973. Neural connections of the visual Wulst of the avian telencephalon. Experimental studies in the pigeon (*Columba livia*) and owl (*Speotyto cunicularia*). *J. Comp. Neurol.* 150: 253-278.

KNUDSEN, E.I. & KNUDSEN, P.F. 1983. Space-mapped auditory projections from the inferior colliculus to the optic tectum in the Barn Owl (*Tyto alba*). *J. Comp. Neurol.* 218: 174-186.

LANGER, G., BONKE, D. & SCHEICH, H. 1981. Neuronal discrimination of natural and synthetic vowels in the field L of trained Mynah birds. *Exp. Brain Res.* 43: 11-24.

MICELI, D., PEYRICHOUX, D. & REPERANT, J. 1975. The retino-thalamo-hyperstriatal pathway in the pigeon (*Columba livia*). *Brain Res.* 100: 125-131.

PIRLOT, P. 1987. Comparative brain morphology in ecological and ethological perspectives. *J. Hirhnf.* 28: 145-211.

SCHALL, U. & DELUIS, J.D. 1986. Sensory inputs to the nucleus basalis prosencephali, a feeding-pecking center in the pigeon. *J. Comp. Physiol. A* 159: 33-41.

SCHALL, U., GÜNTÜRKÜN, O. & DELUIS, J.D. 1986.Sensory projections to the nucleus basalis prosencephali of the pigeon. *Cell Tiss. Res.* 245: 539-546.

STEPHAN, H., FRAHM, H. & BARON, G. 1981. New and revised data on volumes of brain structures in insectivores and primates. *Folia primatol.* 35: 1-29.

WILD, J.M., ARENDS, J.JA. & ZEIGLER, H.P. 1985. Telencephalic connections of the trigeminal system in the pigeon (*Columba livia*); a trigeminal sensorimotor circuit. *J. Comp. Neurol.* 234: 441-464.

WILD, J.M. & ZEIGLER, H.P. 1980. Central representation and somatotopic organization of the jaw muscles within the facial and trigeminal nuclei in the pigeon (*Columba livia*). *J. Comp. Neurol.* 192: 175-201.

ZECHA, A. 1962. The "Pyramidal tract" and other telencephalic efferents in birds. *Acta Néer. Scand.* 5: 194-195.

ZEIER, H. & KARTEN, H. J. 1971. The archistriatum of the pigeon: organization of afferent and efferent connections. *Brain Res.* 31: 313-326.