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# ORGANIZATION OF THE VISUAL PATHWAYS AND VISUAL LATERALIZATION IN THE CHICK

A thesis submitted for the degree of Doctor of Philosophy of the University of New England

By


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I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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## PUBLICATIONS AND COMMUNICATIONS ARISING FROM THIS THESIS

### Referred Papers

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Deng, C. and Rogers, L.J. (1998) Organization of the tecto-rotundal and SP/IPS-rotundal projections in the chick. *Journal of Comparative Neurology*, 394:171-185.

Deng, C. and Rogers, L.J. (1998) Bilaterally projecting neurones in the two visual pathways in the chick. *Brain Research*, 794:281-290.

Rogers, L.J. and Deng, C. (1998) Light experience and lateralization of the two visual pathways in the chick. *Behavioural Brain Research* (in press).

Published Abstracts

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Deng, C. and Rogers, L.J. (1998) Bilaterally projecting neurones in the two visual pathways in the chick. *Proceedings of the Australian Neuroscience Society*, 9:23.

Rogers, L.J. and Deng. C. (1998) Asymmetry of the visual projections to the avian forebrain. *Proceedings of the Australian Neuroscience Society*, 9:178.

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## SUMMARY

This thesis reports research on the organization of the bilateral thalamo-Wulst (thalamofugal pathway) and tecto-rotundal (tectofugal pathway) projections in the chick using fluorescent retrograde tracers. It also examines asymmetry of these projections and the differential contributions of the two visual pathways to functional lateralization.

The research began by examining the abilities of various fluorescent tracers to label the bilateral projections of the two visual pathways. In the thalamofugal pathway, rhodamine B isothiocyanate (RITC), Fluorogold (FG) and True blue (TB) were found to label both the ipsilateral and contralateral projections. However, differential labelling effects were found in the tecto-rotundal projections: RITC and red (rhodamine) beads labelled both the ipsilateral and contralateral projections, but FG, TB and green (fluorescein) beads labelled only the ipsilateral projections. It was found that FG and TB (and maybe also green beads) were taken up by the nerve endings, were transported possibly to the point where the axon collateral branches from the main axon, but failed to be transported to the cell body.

After injecting RITC and FG or TB into the left or right visual Wulst, labelled neurones in the nucleus geniculatus lateralis pars dorsalis (GLd) and the forebrain were examined. The general pattern of labelling in GLd was found to be in agreement with previous reports showing that the cell bodies labelled by tracers injected into the contralateral Wulst are located in the dorsal-lateral parts of GLd and the ipsilateral labelled neurones in the medial-ventral GLd. Although the distribution areas of ipsilaterally and contralaterally labelled neurones overlap partly, very few double-labelled neurones were found (only 0.01% double-labelled neurones). This suggests that the ipsilateral and contralateral projections to the Wulst come from different neuronal populations of the thalamus. In the forebrain, the labelled neurones were found in the neostriatum frontale, pars lateralis (NFl), the neostriatum intermedium (NI), the dorso-lateral neostriatum, and the archistriatum intermedium (AI). These intratelencephalic connections may have significance for the functioning of the visual Wulst in higher information processing.

Using RITC, it was possible to confirm previous findings of asymmetry in the thalamofugal projections. In addition, the asymmetry was definitely located in the contralateral GLd-visual projections because absolute counts of labelled neurones rather than c/i ratio (the ratio of number of contralateral labelled neurones to number of ipsilateral labelled neurones) could be used. The asymmetry is such that there are more projections from the left side of the thalamus to the right visual Wulst of the forebrain than from the right side of the thalamus to the left visual Wulst in the chick.

The organization of the neural projections from the optic tectum (TeO) and pretectal nuclei complex, n. subpretectalis/n. interstitio-pretecto-subpretectalis (SP/IPS), to the n. rotundus (Rt) in chicks was studied using all five tracers. Both the ipsilateral and contralateral tecto-rotundal projections were found to be organised topographically in as much as different sublaminae of the stratum griseum centrale (SGC) project in an orderly manner to Rt and the n. triangularis (T). The deepest stratum of SGC projects to T. Deep SGC projects to the dorsal Rt and superficial SGC projects to the ventral Rt. A band running through the centre of Rt receives input from the central sublamina of SGC, and the caudal central Rt receives input from a deeper sublamina than does the rostral central Rt. The SP/IPS projects to the ipsilateral Rt only and the projection order is dorsal SP to dorsal Rt, ventral SP to ventral Rt and middle SP to the central band of

Rt. The neurones in IPS and the nucleus of the tractus tectothalamicus (nTT) project to T. Thus, Rt and T receive topographically both tecto- (excitatory) and SP/IPS- (inhibitory) projections. The possible functional implications for parallel information processing in these projections are discussed.

FG and RITC were also injected into Rt on each side of the thalamus and the labelled neurones in TeO were examined. In TeO, the distribution areas of the neurones labelled ipsilaterally and contralaterally to Rt overlap completely and up to 45% of the tectal cells were found to be double-labelled by both FG and RITC. Therefore, many tectal neurones have axon collaterals so that they project to the Rt on both sides of the thalamus and must send information simultaneously to both sides of the brain. A two-stage visual transmission model in the tectofugal pathway of the chick was proposed.

Using RITC, we found that the organization of the tectofugal visual projections to Rt was largely symmetrical (males only examined). There are numerous projections from each TeO to its contralateral Rt but, in contrast to reports for the pigeon, no asymmetry was present in these when considered across the entire TeO. However, calculation of the ratio of contralateral to ipsilateral projections for the ventral TeO only revealed significant asymmetry. Symmetry from the dorsal TeO was present in the c/i ratio for projections. Despite this mild asymmetry in the ventral TeO projections, the chick differs from the pigeon which has marked asymmetry in the contralateral TeO-Rt projections.

The contribution of the two visual pathways to lateralization of visual behaviour in chicks was assessed using unilateral injections of 0.5µl of 100 mM monosodium glutamate into localised regions of the forebrain. Glutamate treatment of the left visual Wulst impaired pebble-floor performance and elevated attack and copulation scores, but this did not occur following injection of the right visual Wulst. Thus, the left visual Wulst only is involved in the control of these three visually guided behaviours. By contrast, glutamate injections of the left ectostriatum affected only the attack behaviour and not performance in the pebble-floor task or copulation responses. The results indicate that the tectofugal and thalamofugal pathways have different roles in the lateralization of visual functions.

Functional lateralization of choice between a familiar and an unfamiliar chick was examined using monocular testing. The left eye system (LES) is better able to recognize conspecific individuals and then make a choice to approach one or the other than the right eye system (RES). This lateralization is not dependent on light exposure during the last stages of incubation. However, visual/social experience with broodmates posthatching affects preference and choice: it elevates the ability of RES to recognize conspecific individuals. It is proposed that the tectofugal pathway is involved in this performance, although higher centres must also have a role.

The final chapter discusses how the organization of the two visual pathways may be involved in the neural mechanisms underlying lateralized behaviours tested in this thesis.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AA | archistriatum anterior |
| AChE | acetylcholinesterase |
| AI | archistriatum intermedium |
| AId | archistriatum intermedium, pars dorsalis |
| AIv | archistriatum intermedium, pars ventralis |
| AM | archistriatum mediale |
| AP | archistriatum posterior |
| BIN | binocular |
| CDL | area corticoidea dorsolateralis |
| DAB | diaminobenzidine |
| DIVA | nucleus dorsalis intermedius ventralis anterior |
| DLA | nucleus dorsolateralis anterior thalami |
| DLAlr | nucleus dorsolateralis anterior thalami pars lateralis rostralis |
| DLAmc | nucleus dorsalateralis anterior thalami pars magnocellularis |
| DLL | nucleus dorsolateralis anterior thalami pars lateralis |
| DLLd | nucleus dorsalateralis anterior thalami pars lateralis, pars dorsalis |
| DLLv | nucleus dorsalateralis anterior thalami pars lateralis, pars ventralis |
| DLLvv | nucleus dorsalateralis anterior thalami pars lateralis, pars ventroventralis |
| DLP | nucleus dorsolateralis posterior thalami |
| DLPc | caudal part of DLP |
| DLPr | rostral part of DLP |
| DMSO | dimethyl sulfoxide |
| E | ectostriatum |
| Ep | periectostriatal belt |
| FB | Fast blue |
| FG | Fluorogold |

| | |
|---|---|
| FPL | fasciculus prosencephali lateralis |
| GABA | γ-aminobutyric acid |
| GAD | glutamic acid decarboxylase |
| GLd | nucleus geniculatus lateralis, pars dorsalis |
| GLv | geniculatus lateralis, pars ventralis |
| HA | hyperstriatum accessorium |
| IHA | nucleus intercalatus of hyperstriatum accessorium |
| HIS | hyperstriatum intercalatum superior |
| HD | hyperstriatum dorsale |
| Hp | hippocampus |
| HV | hyperstriatum ventrale |
| HRP | horseradish peroxidase |
| ICo | nucleus intercollicularis |
| LE | left ectostriatum |
| Imc | nucleus isthmi, pars magnocellularis |
| IMHV | intermediate medial hyperstriatum ventrale |
| Ipc | nucleus isthmi, pars parvocellularis |
| IPS | nucleus interstitio-pretecto-subpretectalis |
| LA | nucleus lateralis anterior thalami |
| LdOPT | nucleus lateralis dorsalis nuclei optici principalis thalami; |
| LES | left eye system |
| LN | left neostriatum |
| LW | left Wulst |
| N | neostriatum |
| NC | neostriatum caudale |
| NCL | neostriatum caudolaterale |
| NF | neostriatum frontale |

| | |
|---|---|
| NFl | neostriatum frontale pars lateralis |
| NI | neostriatum intermedium |
| NVE | a group of chicks without visual experience of broodmates (in Chapter 8) |
| nTT | nucleus of the tractus tectothalamicus |
| OM | tractus occipitomesencephalicus |
| OPT | nucleus opticus principalis thalami |
| Ov | nucleus ovoidalis |
| PA | paleostriatum augmentatum |
| PHA-L | phaseolus vulgaris-leucoagglutinin |
| QF | tractus quintofrontalis |
| RE | right ectostriatum |
| RES | right eye system |
| RITC | Rhodamine B isothiocyanate |
| RN | right neostriatum |
| RSd | nucleus reticularis superior, pars dorsalis |
| RSv | nucleus reticularis superior, pars ventralis |
| Rt | nucleus rotundus |
| RW | right Wulst |
| SAC | stratum album centrale of the tectum |
| SE | standard error |
| SGC | stratum griseum centrale of the tectum |
| SGFS | stratum griseum et fibrosum superficiale of the tectum |
| SGP | stratum griseum periventriculare of the tectum |
| SO | stratum opticum |
| SOD | supraoptic decussation |
| SODd | dorsal supraoptic decussation |
| SODv | ventral supraoptic decussation |

| | |
|---|---|
| SP | nucleus subpretectalis |
| SPC | nucleus superficialis parvocellularis |
| SpM | nucleus spiriformis medialis |
| SpRt | nucleus suprarotundus |
| SRt | nucleus subrotundus |
| T | nucleus triangularis |
| TB | True Blue |
| TeO | tectum opticum |
| TPO | area temporo-parieto-occipitalis |
| TSM | tractus septomesencephalicus |
| TT | tractus tectothalamicus |
| VE | a group of chicks with visual/social experience of broodmates (in Chapter 8) |

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