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Current Biology

# Space-Specific Deficits in Visual Orientation Discrimination Caused by Lesions in the Midbrain Stimulus Selection Network

## Highlights

- The orientation of visual contours is analyzed in the birds' forebrain
- A lesion in the midbrain optic tectum causes a loss of orientation discrimination
- A lesion in a local cholinergic circuit causes temporary loss of discrimination
- This midbrain network routes sensory information for perceptual decisions

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## In Brief

Selective attention depends on the ability of the brain to route information according to task demands. Knudsen et al. find that small lesions placed at key nodes in a midbrain network in chickens interfere with their ability to route information about the orientation of visual contours for making perceptual decisions.

Knudsen et al., 2017, Current Biology *27*, 1–12
July 24, 2017 
http://dx.doi.org/10.1016/j.cub.2017.06.011

CellPress

Current Biology
Article

# Space-Specific Deficits in Visual Orientation Discrimination Caused by Lesions in the Midbrain Stimulus Selection Network

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http://dx.doi.org/10.1016/j.cub.2017.06.011

## SUMMARY

**Perceptual decisions require both analysis of sensory information and selective routing of relevant information to decision networks. This study explores the contribution of a midbrain network to visual perception in chickens. Analysis of visual orientation information in birds takes place in the forebrain sensory area called the Wulst, as it does in the primary visual cortex (V1) of mammals. In contrast, the midbrain, which receives parallel retinal input, encodes orientation poorly, if at all. We discovered, however, that small electrolytic lesions in the midbrain severely impair a chicken's ability to discriminate orientations. Focal lesions were placed in the optic tectum (OT) and in the nucleus isthmi pars parvocellularis (Ipc)—key nodes in the midbrain stimulus selection network—in chickens trained to perform an orientation discrimination task. A lesion in the OT caused a severe impairment in orientation discrimination specifically for targets at the location in space represented by the lesioned location. Distracting stimuli increased the deficit. A lesion in the Ipc produced similar but more transient effects. We discuss the possibilities that performance deficits were caused by interference with orientation information processing (sensory deficit) versus with the routing of information in the forebrain (agnosia). The data support the proposal that the OT transmits a space-specific signal that is required to gate orientation information from the Wulst into networks that mediate behavioral decisions, analogous to the role of ascending signals from the superior colliculus (SC) in monkeys. Furthermore, our results indicate a critical role for the cholinergic Ipc in this gating process.**

## INTRODUCTION

Perceptual decisions require both the analysis of sensory information and the selective routing of that information to networks in the brain that mediate cognitive decisions. Interruption of either process will result in an animal being unable to utilize the stimulus for perceptual decisions. In this study, we test the contributions of two midbrain structures, both implicated in the selective routing of visual information based on neurophysiological data [1, 2], to visual perceptual decisions by chickens.

The central visual system in vertebrates contains two major pathways: a retinogeniculate pathway, which projects to primary visual areas in the forebrain, and a retinotectal pathway, which projects to the optic tectum (OT; equivalent to the superior colliculus [SC] in mammals) in the midbrain. In primates, the majority of retinal ganglion cells travel in the retinogeniculate pathway, and this pathway analyzes independent features of the visual scene (for example, contour orientation, color, and motion direction) in specialized circuits in the primary visual cortex (V1) [3]. By contrast, in birds, the majority of retinal ganglion cells travel in the retinotectal pathway, and the OT conveys information about certain features, such as color, luminance, and motion, in parallel pathways to the thalamic nucleus rotundus (Rt; equivalent to the pulvinar nucleus in mammals) [4, 5].

However, at least one visual feature—the orientation of local contours—is analyzed in the retinogeniculate pathway in both birds and mammals. Like in the mammalian V1, neurons in the Wulst are organized in a topographic map of space, the majority respond best to lines of particular orientations, and, in owls, they cluster in orientation columns [6–10]. In contrast, neurons in the dorsal lateral geniculate nucleus (dLGN), which provides visual input to the Wulst, have small visual receptive fields and they are rarely sensitive to line orientation [10, 11]. Therefore, a key transformation in the neural coding for contour orientation occurs in the bird Wulst, as it does in the mammalian V1.

Conversely, there is no evidence that neurons in the OT, or in the forebrain areas that receive input from the OT, respond differentially to the orientation of local contours [4, 12–14]. Neurophysiological studies of the OT, Rt, and entopallium (Ent, equivalent to high-order cortex in mammals) [1]) have demonstrated that neurons in these structures can be selective for stimulus features, such as color, luminance, figure versus ground motion, and motion in depth [4, 15–18]. None of these studies, however, reports tuning for line orientation, a tuning that is easy to detect and that is readily apparent in the Wulst. Based on these data, there is no reason to expect that lesions in the OT should impair the ability of birds to discriminate orientations.