Superior Colliculus Literature Review

Monkey Superior Colliculus

Goldberg and Wurst 1972 (1)

Electrolytic lesions were made by passing 5 ua of anodal current for 60 s/

Studied neurons in the SC of awake behaving monkeys. Made animals fixate and explored receptive fields.

Pan-directional cells

No directional (or orientation) selectivity. Responded equally to round and stationary stimuli. BUT had a really uneven excitatory area. Especially, on the edge of the RF closest to the vertical meridian, the response dropped off abruptly as against the gradual drop off seen on the side away from the VM. Some cells had a weak inhibitory surround while others had a strong inhibitory surround.

Directionally selective cells

Some cells were directionally selective. In some cases they didn’t respond and in other cases, they actively inhibited the response to opposite direction.

Only about 10% of the total cells

Great majority of cells in the cat SC are direction selective.

How much of this difference is due to anaesthesia?

Marocco and Li 1977

Monkey Superior Colliculus: Properties of Single Cells and their afferent inputs; journal of neurophysiology.

Most cells were binocular.

Most cells were not tuned to direction.

Cat Superior Colliculus

Sterling and Wickelgren 1969

Directionally selective cells: No orientation information presented.

Cells in SC respond to stimuli no matter what the size. When stimulus extends past the RF, they show hypercomplex like behaviour.

Most cells did not respond well to stationary stimuli- Gave a brisk response. But sustained response to moving stimuli.

75% directionally selective

None was sensitive to deviations less than 30 degrees (hw\_hh= 60 degrees?)8

More sensitive to dark than to light bars

Predominantly binocular

Cell resemble complex and hypercomplex cells in V1. Particularly hypercomplex

The direction of stimulus movement must change by 30 degrees to have a change in the firing rate. But generally not selective to shape or orientation of the stimulus.

Precise size of the stimulus also not critical.

Wickelgren and Sterling 1968

Important features of the cat superior collicular visual cells are the result of cortical feedback!

Lesioning cortex: lose binocularity and direction selectivity, start responding to stationary stimuli.

Cooling: Reduction in activity in general? Does that mean that all visual input to superior colliculus was from the cortex? What effect does this actually have?

At this point there is yet to be evidence of geniculo-collicular pathway.

Suggest a feedforward model of RF in superior colliculus.

Many cortical cells which are tuned to different directions project to SC cell which then establishes direction selectivity.

Convergence of many hypercomplex cells.

Edwards et al 1979

Sources of subcortical projections to the superior colliculus

-About 40 subcortical structures project to the cat sc. Only visual structures project to the superficial layers of the SC.

Palmer and Rosenquist 1974

Visual Receptive Fields of single striate cortical units projecting to the superior colliculus in the cat.

* “Corticotectal” neurons mostly in layer 5. Were mostly complex cells, mostly binocular, lacked clear length summation and responded to stationary spots of light (unlike other V1 cells)
* Suggest that binocularity and direction selectivity are a product of cortico-tectal projections. But why not orientation selectivity?

Rosenquist and Palmer 1971

Lesioned V1 in cats

Proportion of cells tuned to direction decreased. Proportion of cells that were binocular decreased- mostly driven by contralateral eye. Lesions in 18, 19 and PMLS did not produce this effect.

No changes in proportions of cells showing surround inhibition, internal inhibition or summation after cortical lesions.

Fries 1984

Cortical projections to the superior colliculus in the macaque monkey: A retrograde study using horseradish peroxidase

Corticotectal cells: In V1, V2 and V3; FEF and premotor area.

Rodman, Gross and Albright, 1990

Afferent basis of visual response properites in Area MT of the Macaque. Effect of SC removal.

Area MT- when SC is removed there is still response. Not the alternate source of input to MT. Removing V1 and SC- silences all visual responsiveness.

Still doesn’t explain the other source of input. Just not SC? Maybe all of SC not destroyed?

Rodent Superior colliculus

Comoli et al., 2012

Segregated Anatomical input to subregions of the rodent superior colliculus associated with approach and defense

A lot of neurons do defensive stuff in rodent sc

And defense and appetitive behaviour are entirely segregated.

Phongphanphanee et al, 2014

Distinct local circuit properties of the superficial and intermediate layers of the rodent superior colliculus

In-vitro whole cell study

Centre-surround organisation in superficial layers of the SC  
Most interactions were non-linear.

In contrast the internmediate layers of SC acted linearly.

Suggests that lateral interactions of superficial SC help to localise salient stimuli whereas the intermediate SC help in saccadic decision making.

Vokoun et al., 2010

Intralaminar and Interlaminar activity within the rodent superior colliculus visualised using voltage imaging

Invitro study, voltage imaging to study neural circuitry

Stimulation of Superficial SC- response spread in all directions and also across layers. Figure 3: Mostly laterally with a little bit of response extending ventrally.

Stimulation of intermediate SC- response first spread dorsally into the superficial SC- maybe antidromal? Would explain the smaller latencies.

Stimulation of SGI turns on inhibitory circuits in SGI and excitatory circuit in SGS and SO- look at latencies!

Look at references

Comoli et al, 2003

A direct projection from superior colliculus to substantial nigra for detecting salient visual events.

Antrerograde and retrograde tract tracing using light and electron microscopy.

Checked with ephys

Short latency response in substantia nigra was lost when SC was lesioned

Reviews

May, 2006 ( Paul J. May is author)

The mammalian superior colliculus: laminar structure and connections

Thoughts

* Majority of the orientation biases are inherited from the visual cortex- But this doesn’t happen in any other species…
* Orientation biases inherited from the LGN- which gets its biases from?
* Finally, in the layers we recorded from, a lot of the inputs are from retina (95%).

Vanni et al., 2015

Spatiotemporal Profile of Voltage-Sensitive Dye Responses in the Visual Cortex of Tree Shrews Evoked by Electric Microstimulation of the Dorsal Lateral Geniculate and Pulvinar Nuclei

Electrically stimulated LGN and Pulvinar (SC projects to Pulvinar)

LGN stimulation activated V1. Pulvinar stimulation activates extrastriate areas (not V1).

EC activation latencies and magnitudes similar. So is the pulvinar activation direct?

Visual Receptive Field Properties of Neurons in the Superficial Superior Colliculus of the Mouse

Lupeng Wang, Rashmi Sarnaik, Krsna Rangarajan, Xiaorong Liu and Jianhua Cang

2010 J.Neurosci

Mouse SC: Mostly y-like cells. Orientation and direction selective.

Removing cortex did not affect orientation selectivity whereas increased direction selectivity of the neurons- probably derive orientation tuning from the retina.

Say that non-linearity comes from spatial segregation of on and off sub-fields- but could be due to the high proportion of Y-cell inputs.

**Y cells project to SC**

Antidromic activation (Schiller and Malpeli, 1977; DeMonasterio, 1978) and retrograde tracing (Bunt et al., 1975; Leventhal et al., 1981) experiments concluded that the largest-bodied, fastest-conducting cells projected to the superior colliculus.

Bunt AH, Hendrickson AE, Lund JS, Lund RD, Fuchs AF (1975) Monkey retinal ganglion cells: morphometric analysis and tracing of axonal projections with a consideration of the peroxidase technique. J Comp Neurol 164:265–285.

DeMonasterio FM (1978) Properties of concentrically organized X and Y ganglion cells of macaque retina. J Neurophysiol 41:1394–1417.

Leventhal AG, Rodieck RW, Dreher B (1981) Retinal ganglion cell classes in the old world monkey: Morphology and central projections. Science 213:1139–1142.

Schiller PH, Malpeli JG (1977) Properties and tectal projections of monkey retinal ganglion cells. J Neurophysiol 40:428–445.

Neurons in the Most Superficial Lamina of the Mouse Superior Colliculus Are Highly Selective for Stimulus Direction

Samsoon Inayat,1,4,\* Jad Barchini,1,2,\* Hui Chen,3 Liang Feng,3 Xiaorong Liu,1,3 and Jianhua Cang corresponding author1

2015 J. Neurosci

Cortical projections to the superior colliculus in tree shrews (Tupaia belangeri)

Mary K L Baldwin,1 Haiyang Wei,2 Jamie L Reed,1 Martha E Bickford,2 Heywood M Petry,3 and Jon H Kaas1

Injected retrograde tracers in to SC. Found projections to V1 and V2; labelled temporal visual cortex but no projections from posterior parietal cortex.

([Murphy et al., 2001](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3604183/#R52); [Meredith et al., 2011](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3604183/#R50))- tree shrews are close evolutionarily to rodents and primates.

1. Murphy WJ, Eizirik E, O’Brien JO, Standhope MJ, DeJong WW, Springer MS. Resolution of the early placental mammal radiation using Baysian phylogenetics. Science. 2001;294:2348–2351.[[PubMed](https://www.ncbi.nlm.nih.gov/pubmed/11743200)]

Meredith RW, Janecka JE, Gatesy J, Ryder OA, Fisher CA. Impacts of cretaceous terrestrial revolution in KPg extinction on mammal diversification. Science. 2011;334:521–524.

Retinal Origin of Direction Selectivity in the Superior Colliculus

Xuefeng Shi,1,4,\* Jad Barchini,1,\* Hector Acaron Ledesma,2 David Koren,2 Yanjiao Jin,1,5 Xiaorong Liu,1,3 Wei Wei,2 and Jianhua Cang1

Fancy mixture of in-vivo electrophysiology and optogenetics . Found that direction (but also orientation selectivity ) in rodent SC was inherited from the retina.

Colour and pattern selectivity of receptive fields in superior colliculus of marmoset monkeys

Chris Tailby, Soon Keen Cheong, Alexander N. Pietersen, Samuel G. Solomon, Paul R. Martin

Colour information to SC neurons not from S-cones but rather from the cortex.

DI= 0.17 and OI= 0.15

Orientation columns in the mouse superior colliculus Evan H. Feinberg1 & Markus Meister1,2

Show orientation columns in the mouse SC but no retinotopic organization of the superior colliculus.

Functional Identification of a Pulvinar Path from Superior Colliculus to Cortical Area MT

Rebecca A. Berman and Robert H. Wurtz

Pathway from SC to MT via pulvinar in awake behaving macaques. Stimulated neurons in the pulvinar and found that a subset of neurons received inputs from the SC and also projected to MT. More evidence that this alternate pathway exists.

Projection of the Mammalian Superior Colliculus Upon the Dorsal Lateral Geniculate Nucleus: Organization of Tectogeniculate Pathways in Nineteen Species

Harting et al., 1991 Journal of comparative neurology

Neurons in the superficial gray project to the LGN and the area of SC from which these projections arise are W-like projections.

The superficial layers of the superior colliculus which form a separate visual pathway to the visual cortex via the pulvinar allows form perception to be preserved when the V1 is damaged. The V1 is said to be the source of visual perception. Behavioural studies (humans and macaques) show that conscious perception of sight is lost when the V1 is damaged. However, these subjects still demonstrate some visual function (blindsight). Lesion studies in the tree shrew show that when the V1 is lesioned, the animals were unable to attend to non-salient cues but were still able to detect changes in salient features (eg: unable to detect changes in orientation when colour was present, Killackey & Diamond, 1971). However, when extrastriate cortex is lesioned, the tree shrews were incapable of adapting to changing cues. The functional deficits demonstrated by lesioning the temporal cortical areas are also seen when the visual areas of the superior colliculus are lesioned (Killackey & Diamond, 1971; Casagrande et al., 1972; Killackey & Diamond, 1973). This preservation of form discrimination in the tree shrews following lesions to the visual cortex is presumably due to the alternate pathway to the extrastriate regions via the superior colliculus. This pathway has also been implicated in "blindsight" phenomenon described earlier (see Payne et al., 1996 for review).

Although the tree shrew superior colliculus is functionally well characterised, there is little known about the receptive fields of the superior colliculus. Only one study of the receptive fields of the tree shrew superior colliculus has been conducted. Albano et al (1978) examined the receptive field properties of the tree shrew superior colliculus. Albano et al reported that the tree shrew superior colliculus neurons showed poor direction selectivity and a small proportion of neurons (~20%) were tuned to orientation (response at optimum orientation greater than 3 times the response at non-optimum orientation). Albano et al (1978) also showed that the properties of the superior colliculus neurons varied with the depth at which they were recorded from. These properties have not been further studied in the tree shrew superior colliculus. One aim of this study was to characterize the response properties of the superior colliculus neurons.

In this study we predominantly aimed to characterize the orientation selectivity of the neurons in the tree shrew superior colliculus.