A model tectum: attention, synchrony and behavior.

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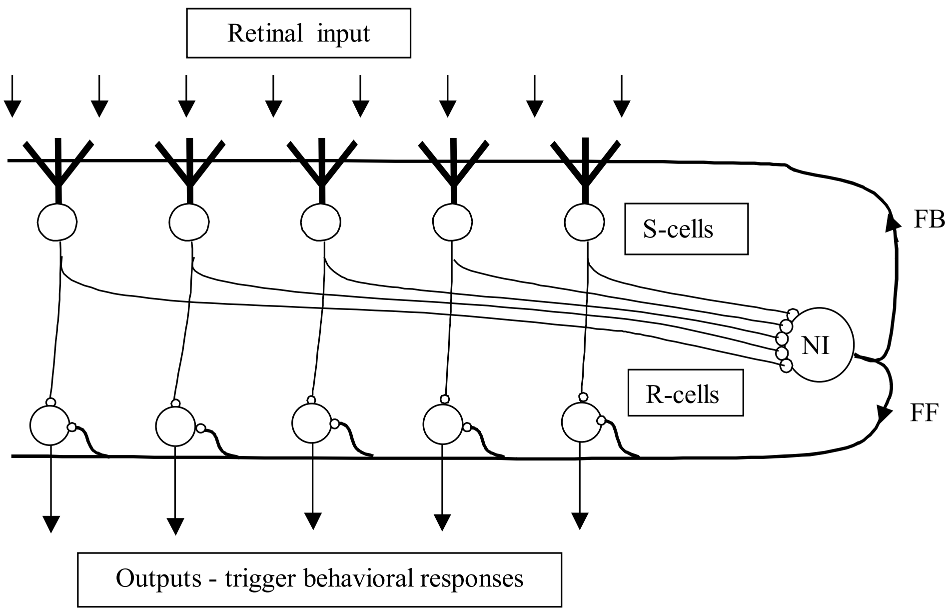
1. Functions of tectum

The optic tectum of the midbrain is the preeminent visual center in nonmammalian vertebrates, although many mammals such as rodents, depend heavily upon it too. Tectum should also be thought of as multimodal processor because sensory inputs from other modalities are mapped on it in topographic register with the retinal input. Whether an animal runs, crawls, flies or swims, the tectum is critical for localizing events and objects in the immediate environment, assessing their significance (desirable to approach or to flee), and initiating appropriate motor responses. However, before action is taken, an attentive process intervenes to select the object or event to respond to, permitting focal activation of a motor map deep in tectum. A set of motor pattern generators are then triggered, leading to well directed approach or avoidance behaviors. Using tectum as a ground plan, we are building a sensorimotor system implemented with spiking silicon neurons to control the behavior of a robot. For details of the neuromorphic hardware and the artificial dendritic tree neuromorph see Northmore & Elias (1999) and http://neuro.ee.udel.edu/.

Our experiments with fish suggest mechanisms for the selective/attentive processes in the following situation. Fish orient accurately and rapidly to a brief light flash signaling food, a behavior known to depend upon tectum. When two flashes are presented simultaneously, anywhere in the visual field, fish orient accurately to one of them with very little hesitation. Subsequently they may orient less accurately to the position of the other. We hypothesize that rapid selection may be performed by tectum in conjunction with the nucleus isthmi (NI) that lies deep and posterior to the tectum (Northmore 1991). The tectum sends excitatory connections to NI, and it receives reciprocal connections back from NI that are primarily excitatory. NI responds with bursting activity to sensory stimulation that is novel or particularly salient. Because of electrical coupling between cells within NI, the nucleus acts as a unit, broadcasting the same activity pattern over the entire tectum. We have simultaneously recorded in deep tectum and NI, and found spiking activity synchronized to within 1 msec. Synchrony occurs in bouts varying from a few 10’s to a few 100’s of ms., and not directly time-locked to sensory stimulation.

2. The model

The figure shows the basic model, which is consistent with the known physiology and anatomy of the fish tectum. The S-cells receive retinal inputs and are retinotopically arrayed. They are feature detectors of various kinds e.g. for stimulus pattern, movement, or color, and they habituate to repeated stimulation in the same retinal area. Thus, the S-cells form a salience map. S-cells make excitatory connections with cells of NI. Behaving as a unit, NI broadcasts bursts of spikes back to the tectum. NI's activity may be selective for events represented in the S-cell salience map in two ways. (1) If NI activity represents a MAX function of salience, it could be transmitted via feed-forward connections (FF) to the R-cells acting as comparators. Only the strongest S-cell activity will excite a topographically corresponding set of R-cells, triggering a behavioral response. Thus, it is the most salient event (e.g. a light flash signaling food) rather than all the other boring stimuli around that elicits a behavioral response (e.g. orientation) in the appropriate direction in space. (2) An alternate mechanism, simlar to a model of attention involving a central and multiple peripheral oscillators (Borisyuk et al 2000) is suggested by the bouts of close synchrony between tectal and NI spike activity. In this scenario, NI spike bursts via feed-back connections (FB) synchronize with a set of S-cells that represents a salient event. For this to occur the set of S-cells would have to be driven by the event to respond simultaneously, and with similar amounts of firing. The S-cell set, whose synchrony is promoted by NI, is then able to excite the appropriate R-cells and trigger a behavioral response. The appeal of this scheme is that stimulus elements widely separated in the visual field could be bound together as one instigating stimulus or object of attention. An example is a looming visual stimulus whose expanding retinal image creates an expanding boundary of activity on the tectum. We found that this stimulus excites NI very vigorously. Synchrony or no synchrony, the fish attends, and swiftly avoids.



References

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