PARALLEL INTEGRATION OF VISUAL INPUTS EVOKING DISCRETE MOTOR PATTERNS LEADING TO COORDINATED AVOIDANCE BEHAVIORS

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2. LEDs Were Used As Light Stimuli

4. Leeches Shorten In Response To UVR On The Head, But Extend When It Is Shone On The Tail

Larger and fed individuals were tested using each LED at both head and tail in addition to oral jaws. In total, 9 individuals were randomly selected and exposed to each LED in randomly selected order and position. A response was scored if it occurred within 5 s of exposure. In virtually all cases, oral jaws at the head resulted in a startle-like whole body shortening while the same stimulus at the tail resulted in a more complex whole body extension, often followed by crawling or swimming for an extended period.

5. UVR Is Detected As A Visual Stimulus

The system is well positioned as a model to investigate the way in which diverse sensory modalities are integrated by the central nervous system to produce adaptive behaviors.

6. Many Photoreceptors Are Broadly Tuned While Other Are Narrowly Tuned

Single photoreceptor responses to light recorded using sharp intracellular electrodes. A: Most cells are broadly tuned, responding well to UVR and visible wavelengths (C-B). B: About 10% of cells so far are more narrowly tuned to UVR (C-A). C: Cells appear to have 2 peaks of sensitivity, around UVR and Green with populations biased toward one or the other.

8. UVR Is Discrete And Parallel To Other Inputs

The S-cell will respond vigorously to touch on the skin (arrowheads) as well as UVR. Intracellular microelectrodes were used to record sequentially from the S-cell (A-B), a touch sensitive primary neuron (B-L), the Pressure sensitive primary neuron (C-G), and a Nitric oxide sensitive neuron (D-F). Action potentials were monitored in all conditions by an extracellular electrode. These experiments confirm that UVR input to the S-cell are discrete and not acting via mechanosensory pathways.

Conclusions. 1. Leeches can detect UVR as a visual stimulus. 2. They distinguish between UVR and visible light, but the mechanism remains to be determined. 3. UVR is mapped onto higher order neurons, as one of a set of parallel, multimodal inputs.

Thus, this preparation can be used to address how the CNS integrates many inputs and makes decisions about adaptive behavior.

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1. The Eyes Have It

The system is well positioned as a model to investigate the way in which diverse sensory modalities are integrated by the central nervous system to produce adaptive behaviors.

3. Leeches Avoid UVR And Escape From It

A. Groups of 20 unfed juvenile leeches were randomly selected and placed onto each of 5 groups for group subjects testing. Each wavelength was presented in a random order and in a randomly selected order for 60 s. Each wavelength was presented for 3 times and the number of leeches in the illuminated quadrant was determined at 15 s intervals. These were used to calculate a simple fraction reflecting the percentage of leeches that choose the quadrant. B. Groups of leeches exhibited no response to red or blue light over the 60 s period, and a long latency, relatively weak response to white and green light, consistent with past work. The UVR stimulus resulted in a short latency and robust negative photo-tactic response.

*Notably, I observed that leeches extended, crawled or swam out of the field if already in it. Yet if retracted from the illuminated field if they entered it with their heads. These involve very discrete and different motor programs.

It has been known that leeches, like vertebrates, detect blue light with a peak sensitivity in the green to 400 nm. But, they are fairly photoneutral showing with satiation when satiated and will excrete when hungry.

The medicinal leech, Hirudo sp, is an annelid worm with an experimentally tractable nervous system and behavior. The worm is an aquatic predator with a complex sensorium. There are 5 pairs of cephalic eyes along the dorsal margins of the anterior sucker. Each one of these pigmented eyepatches houses about 50 individual photoreceptor nerve cells. Additionally, there are 14 pairs of simple sensilla containing photoreceptors in each of the 21 body segments, thus, these worms have a greatly expanded visual field and can detect light at the head, tail and along the body, and dorsal to ventral.

The medicinal leech, Hirudo sp, has an innate visual system with 5 pairs of pigmented cephalic eyes at the anterior margin of the auditory organ and of 2 pairs of simple sensilla containing photoreceptors arranged dorsoventral to ventral in the central and subventral oral jaws body region of Hirudo. While Hirudo has a pair of simple sensilla including photoreceptors arranged dorsoventral to ventral in the central sensory organs, Hirudo lacks eyes and more distantly related insects like Drosophila. The medicinal leech, Hirudo, has an innate visual system with 5 pairs of pigmented cephalic eyes at the anterior margin of the auditory organ and of 2 pairs of simple sensilla including photoreceptors arranged dorsoventral to ventral in the central and subventral oral jaws body region of Hirudo. While Hirudo has a pair of simple sensilla including photoreceptors arranged dorsoventral to ventral in the central sensory organs, Hirudo lacks eyes and more distantly related insects like Drosophila.

A. semi-intact preparation was developed to allow for simultaneous intra- and extracellular recording from identified neurons in the CNS while stimulating the animal using multiple modalities and across different body regions. In a first effort of mapping UVR responses, I chose to assess the response of the S-cell, a neuron of the fast conducting pathway known to be involved in startle responses and whole body shortening. It is a semi-intact-tissue histology of S-cell responses shows that input is strong for both UVR and Green, at both head and tail with some asymmetry. Interestingly, there is a measurable response to blue (and less so to red) light, yet blue and red light does not evoke any detectable behavioral response. Thus, it is clear that additional neurons must be involved and should be discernible by mapping using this preparation.

A. LEDs offer a way to generate relatively narrow ranges of wavelengths to be used as stimuli. I made simple hand held wands using LEDs and fixed resistors selected to yield a defined output. Shown here are the 4 most commonly used LEDs, Red, 615-640 nm, Green, 515-520 nm, Blue, 450-470 nm, UVR, 395-405 nm. Also used were White, 500-600 nm, IR, 850 nm, and 2 other UV ranges, 380-385 nm and 360-385 nm. When the strengths were examined across a range of transmittance (using NCX and NC2 filters), all were approximately equal, with the UVR being the least "intense."

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7. A Higher Order Interneuron Involved In Rapid Whole-Body Movements Is Excited By UVR

The 5-cell will respond vigorously to touch on the skin (arrowheads) as well as UVR. Intracellular microelectrodes were used to record sequentially from the 5-cell (A-B), a Touch sensitive primary neuron (B-L), the Pressure sensitive primary neuron (C-G), and a Nitric oxide sensitive neuron (D-F). Action potentials were monitored in all conditions by an extracellular electrode. These experiments confirm that UVR input to the S-cell are discrete and not acting via mechanosensory pathways.

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