Overview

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

1. The Eyes Have It

2. LEDs Were Used As Light Stimuli

3. Leeches Avoid UVR And Escape From It

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

5. UVR Is Detected As A Visual Stimulus

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

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

The Eyes Have It

Leeches have been known that leeches react to blue light with a peak sensitivity in the green of 480 nm. But, they are fairly photoneutral showing resonance when satiated and with extra locomotion when hungry.

The medicinal leech, Hirudo spp. 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 eyecups houses about 50 individual photoreceptor neurons. 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.

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 quanta of output. Shown here are the 4 most commonly used LEDs: Red, 615-640 nm; Green, 515-530 nm; Blue, 440-470 nm; and UV, 395-405 nm. Also used were white, 500-600 nm, IR, 850 nm, and 2 other UV ranges, 380-385 nm and 360-365 nm. When the strengths were examined across a range of transmittance (using NCtrome NC Filters), all were approximately equal, with the UVR being the least “intense.”

A. Groups of 20 unfed juvenile leeches were randomly selected and placed into each of 5 groups for group subjects testing. Each wavelength was presented in a random order with 60 s. Each wavelength was presented 3 times and the number of leeches in the illuminated wavelength was determined at 15 s intervals. These were used to calculate a simple fraction reflecting the percentage of leeches that had the quintile. 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 UV 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 retracted from the illuminated field if they entered it with their heads. These involve very discrete and different motor programs.

1. A semi-intact preparation was developed to allow for simultaneous inter- 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. A per-stimulus time histogram of S-cell response 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 discoverable by mapping using this preparation.

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) a tactile sensitive primary neuron (B) the Pressure sensitive primary neuron (C) and a Nocticeptive neuron (D). S-cell 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 mechanisms 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.

This work was funded in part by a Faculty Research and Creative Activities Award from Western Michigan University and National Science Foundation grants NSF-0505905 and 0906332. The undergraduate student investigators, Thomas Falbo, Ben Guglielmi, and Daniel Monforte, and the graduate students, G. Zayas, D. C. Roach made major contributions to this work.