Immediately after the ultraviolet stimulus was removed. In contrast, changes in fluorescence with NP-EGTA-loaded cells persisted for many seconds after the UV stimulus was turned off. Additionally, the size of the fluorescent signal did not decay with subsequent UV stimuli.

Our work demonstrates that local stimulation of caged calcium trapped within horizontal cells by ultraviolet light delivered by small optic fibers can be used to increase intracellular levels of calcium in isolated horizontal cells. For future studies, this approach must be modified to achieve the proper spatial resolution of calcium uncaging. Currently, we are examining various methods to decrease the UV light output of the pulled optical fiber by adding neutral density filters and optimal alignment of the laser source. We hope to use this technique, in conjunction with self-referencing recordings of H⁺ flux from horizontal cells, to examine the spatial dependence of proton flux from these cells.

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Literature Cited


Neural Recordings From the Lateral Line in Free-Swimming Toadfish, Opsanus tau

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Fish and aquatic amphibians have evolved a unique lateral line system that detects local water displacements. The lateral line functions in surface feeding, rheotaxis, localization of underwater objects, and subsurface prey detection (1). The detection of biologically relevant stimuli must often be accomplished during reafferent stimulation from self-generated motion (swimming, ventilation). However, due to the constraints of conventional recording techniques, the activity of the lateral line during movement is difficult to quantify.

The development of an inductive telemetry system (2) enables neural activity to be recorded from free-swimming fish. The system utilizes inductive telemetry to transmit biological information from the fish to an external recording device. Consequently, fish are free from constraints and are able to behave in a quasi-natural environment. Using this technique, we investigated the activity of primary afferent fibers of the anterior lateral line nerve during self-induced motion in the oyster toadfish, Opsanus tau. Adult toadfish (28 ± 1.4 SE cm standard length, 675 ± 46 SE g) of either
sex were lightly anesthetized in 0.001% tricaine (Sigma) and lightly paralyzed with pancuronium bromide (Sigma) (600 μg/kg). A microwire electrode was inserted into the dorsal ramus of the anterior lateral line nerve, which innervates the supraorbital and infraorbital lateral line (3). Once spontaneous or evoked activity of 1 to 3 afferent fibers was obtained, the electrode was attached to a cylindrical telemetry tag (15 mm diameter x 38 mm length) and mounted externally on the dorsal surface of the fish. The rechargeable telemetry tag was inductively coupled to a bimodal recording stage (45 cm diameter). The stage acts passively to receive the inductive telemetry signal and actively to produce the magnetic field necessary to recharge the capacitors on the tag. The fish is free to move throughout the aquarium; however, data acquisition and tag charging are only possible when the fish remains on or near the stage. Fish were placed on the stage in an experimental tank (1.6 m diameter, 20 cm water depth), and allowed to recover from the surgical procedure for at least 3 h before experiments were conducted.

Fish movement was monitored with a digital camera (30 frames/s) and correlated with nerve firing of the anterior lateral line (ADInstruments, Chart4; Cambridge Electronic Designs, Spike2). Spontaneous neural activity was recorded in each fiber and correlated with ventilation cycles. Nerve firing was also recorded when the fish moved independently or was provoked into swimming by gently prodding its caudal fin with a rod. All swimming events consisted of short swimming bursts that displaced the fish up to a body length forward. Swimming speeds (range: 3.6–15.1 cm/s) were determined by videotape analysis.

The primary afferents of the anterior lateral line in the toadfish increased firing in response to swimming and ventilatory movements. During forward swimming, the firing rate of the anterior lateral line increased above spontaneous rates (Fig. 1A), and neural activity returned to spontaneous rate within 2 s. There was no correlation (r^2 = 0.07) between swimming speed and firing rate, suggesting that firing was saturated at all swimming events. This contrasted with previous work that indicates lateral line afferent activity is reduced during vigorous body movement (4). Anterior lateral line afferents were also stimulated by ventilatory movements (Fig. 1B). The responses of 15 (6 silent and 9 spontaneously active) fibers to the ventilatory cycle were monitored. Three silent fibers and three spontaneously active fibers fired in correlation with the exhalation phase of the ventilation cycle. The other nine fibers were not modulated by ventilation; however, we were unable to determine whether this was due to the distant location of the neuromast from the operculum or to efferent inhibitory activity.

Efferent stimulation has been shown to reduce the activity of afferent fibers of the lateral line (5). Other studies also illustrated efferent inhibition of the lateral line in response to visual octavolateralis stimuli (6). However, in this study, all fibers were activated by swimming and 40% were activated by ventilatory activity. Thus reafferent noise does not appear to be inhibited by efferent activity at the primary afferent level. Consequently, self-generated noise is possibly filtered from the signal in higher order neurons. Bodznick and Montgomery (7) indicate that the lateral line medullary nuclei contain an adaptive filter capability that cancels inputs consistently associated with an animal's own movements. Fish are generally mobile animals; however, the ability of the lateral line to function

Figure 1. Neural activity of the anterior lateral line in Opsanus tau in response to reafferent self-generated motion. (A) The response of two fibers to short-range swimming events. The dashed black line represents the spontaneous activity of each fiber. The solid black line represents a linear regression through all data points (upper: y = −5.5x + 158.4, r^2 = 0.07; lower: y = −0.9x + 58.3, r^2 = 0.02). (B) Neural trace of a silent fiber (i.e., fiber with no spontaneous activity) that was responsive to the ventilation cycle. The fiber innervated a neuromast located on the infraorbital canal line. Arrows indicate the period of maximum operculum abduction during the ventilation cycle (measured by video analysis).
during self movement is largely unknown. This study reports preliminary findings of enhanced nerve activity of the anterior lateral line during self-generated motion, indicating that perhaps mechanosensory noise is not inhibited in afferent activity.

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Memory Reconsolidation in *Hermissenda*

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Remembering seems *a priori* to be composed of three main processes: acquisition (or input), storage (or consolidation), and retrieval (or recall) (1). In this study the acquisition of memory is the form of Pavlovian conditioning elaborated by Lederhendler et al. (2).

The consolidation of this conditioning in *Hermissenda* was studied by Epstein et al. (3). Consolidation of memories has been known experimentally at least since Müller and Pizcker (4) demonstrated it in humans in 1900. It is defined as the process by which memory reaches a state in which interventions (or interferences) no longer inhibit recall of what was presented to be remembered. This does not mean, as initially inferred (5, 6), that the installed memory cannot be altered; it is just that it is stable with respect to the said interferences. Examples of such interventions include the four treatments (chemicals, sensory input) used in this study.

Reconsolidation (a much newer finding) is defined as the ending of the interference-insensitive state brought about by the recall of what was memorized. That is, after a memory has been consolidated, if it is recalled it becomes sensitive to agents such as inhibitors of mRNA synthesis and protein synthesis that did not affect it just before the recall. Since the consolidated memory is regenerated after recall, it will become important to determine whether the fact of reconsolidation has more to do with temporary memory degradation or with a weakening of the retrieval process.

Consolidation and reconsolidation are being studied in many organisms from molluscs to humans (5, 6, 7, 8). The existence of reconsolidation may allow more detailed study of many proposed aspects of consolidation. We therefore undertook a preliminary study of reconsolidation in *Hermissenda*. This nudibranch has proven to be a high-connectivity model for the more complex vertebrate nervous system, especially in the area of learning and memory (3, 9, 10).

Our training procedure with *Hermissenda* was a Pavlovian conditioning regime (2). Animals were placed in transparent acrylic plastic trays (with 16 fluid-filled lanes about 0.9 cm wide and deep and 15 cm long) in a closed 1°C incubator for 10 min of dark adaptation before training or testing. Training consists of exposing the animals to a bright white light (650–700 lux) for 6 s (the conditioned stimulus, CS), paired, after a 2-s delay, with a 4-s vigorous orbital shaking of the tray containing the animals (the unconditioned stimulus, US). The animals respond to the shaking by contracting lengthwise. This combination of the two stimuli is called a paired training event (TE) and is repeated at 1-min intervals.

Testing of recall was done by four presentations of the CS at 1-min intervals, and was recorded using a videocassette recorder whose input was registered by a camera placed below the transparent trays. Animal length was measured on the video monitor. The measure used was the percentage by which the animal’s length changed between light-on and light-off times. From those percentage changes we compute a mean and the standard error of the mean.

We used four interventions after training to probe the acquisition and consolidation of memory in *Hermissenda*. The first intervention is the sensory input used by Epstein et al. (3). The other three are drugs dissolved in seawater, pH 8, and administered by replacement of the seawater bathing the animal.

1. Sensory input: the tray containing the animals is quickly rotated by hand 180° around its long axis and, after 5 s, quickly rotated back to its original position. This produces a vestibular input (in addition to the TE) and is termed a sensory block (SB).

2. Anisomycin (ANI) interferes with protein synthesis by in-