Sensory Percepts Elicited by Macrosieve Stimulation of the Rat Sciatic Nerve

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Background

Electrical stimulation of truncated peripheral nerves elicits phantom sensations in an amputated limb [1]. Electrode implants can serve as portals between truncated nerve stumps and embedded prosthetic sensors, providing an avenue for introducing sensory feedback into the nervous system originating in a prosthetic limb. We describe a rat behavioral model for comparing the sensory performance of implanted cuff and macrosieve electrodes

Extraneural Cuff Electrode (ECE)

The ECE is a non-invasive implant that wraps around an intact nerve. It consists of a silastic sheath whose inner surface is lined with platinum leads. The ECE provides robust control of axons located on the nerve's external surface. Selective control of interior axons is limited.

Macrosieve Electrode (MSE)

The MSE consists of a flat disk with 8 spokes radiating from a central hub. The spokes and hub together bound 9 "transit holes." Interspersed platinum leads provide electrical stimulation. The MSE is implanted between the distal and proximal stumps of a transected nerve. Regenerating axons from the proximal stump pass through the transit holes. Contacts between regenerated axons and electrode surfaces are stable and supportive of chronic implantation.

Approach

To establish whether rats can detect electrical stimulation of the sciatic nerve using a behavioral paradigm:

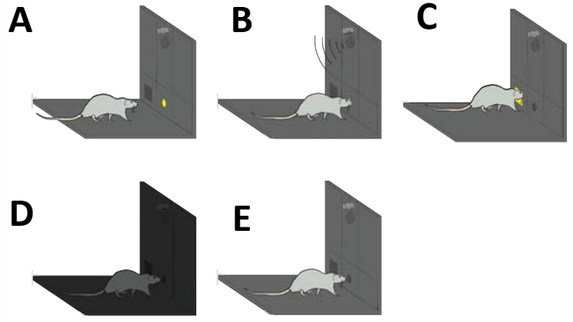
Stage 1 - Select rats that successfully learn a go/no-go detection task with auditory stimuli.

Stage 2 - Implant ECEs/MSEs and construct a head-cap interface.

Stage 3 - Resume training with non-painful electrical stimuli in conjunction with auditory stimuli.

Stage 4 - Gradually reduce auditory intensity until rat responds solely to electrical stimuli.

Go/No-Go Auditory Detection Task



A. A Skinner box has a snout detector, 20-mg food pellet dispenser, 2,900-Hz tone generator, and house light.

B. A trial begins with snout detector cue light onset. The rat must insert its snout and maintain snout-insertion for a randomized interval (3 ± 1.5 s), which leads to auditory stimulus.

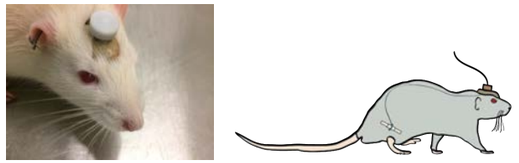
C. Food reinforcement occurs when the rat withdraws within 500 ms of stimulus onset.

D. A 7-s timeout with extinguished house light occurs when the rat withdraws prematurely, before stimulus onset.

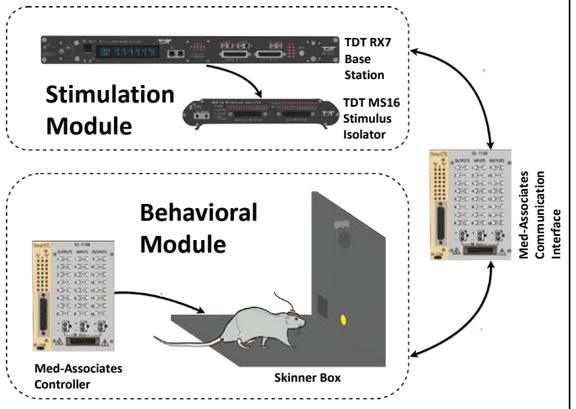
E. Late withdrawal > 500 ms after onset imposes a 3-s delay before the next trial.

Implantation & Head-Cap Construction

- Anesthetize rats with isoflurane.
- Expose sciatic nerve and skull through right thigh and scalp incisions.
- Affix Omnetics/electrode assembly to the sciatic nerve.
- Route Omnetics connector and trailing wires subcutaneously to the skull.
- Encase Omnetics connector in an acrylic head-cap.



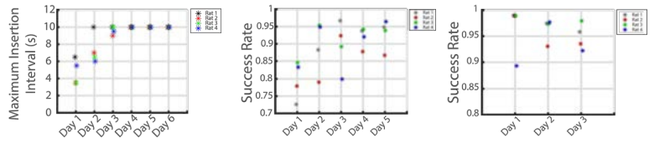
Apparatus



Preliminary Results

A. 4 rats trained on go/no-go auditory detection task in 5 stages.

- Stage 1: Rats associated the food pellet dispenser with food pellets.
- Stage 2: Rats learned to insert their snouts into the detector for food pellets.
- Stage 3: Rats learned to insert their snouts for progressively longer intervals.
- Stage 4: Rats learned to withdraw within 500 ms of stimulus onset.
- Stage 5: Rats graduated to the main auditory detection task, with randomized insertion intervals and reinforced withdrawals.



B. The rats subsequently underwent surgery for ECE implantation and head-cap construction.

C. EMG recordings of tibealis anterior and plantaris muscles revealed a 150-uA motor threshold. This threshold provided a tentative estimate for a current amplitude that would elicit a sensory percept.

D. The rats relearned the auditory detection task. Subsequently, sciatic stimuli (150 μA) were presented in conjunction with auditory stimuli.

E. Removal of auditory stimuli resulted in rats quickly transferring attention exclusively to sciatic stimuli.

Future Work

Systematic variation of current intensity will enable generation of psychometric curves. Future rats with MSE implants will similarly learn a go/no-go detection task through stimulation of sub-fascicular axon clusters. A current steering paradigm will selectively activate these axon clusters [2].

References

[1] Tan, Daniel W., Journal of neural engineering 12.2 (2015): 026002.

[2] MacEwan, Matthew R., Frontiers in neuroscience 10 (2016): 557