Toward Clinical Translation of the Intelligent Spine Interface Project

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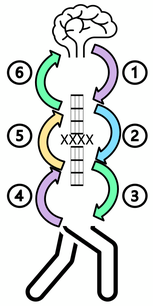
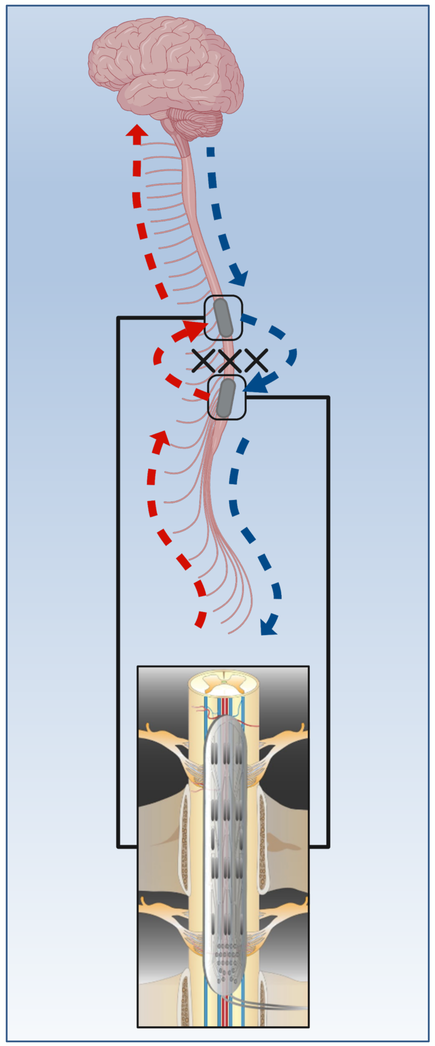
Highlights

- The Intelligent Spine Interface (ISI) Project consists of an implantable spinal electrode device that **bypasses severed neural connection** due to spinal cord injury.
- The ISI can **bidirectionally read and write to the spinal cord** above and below the injury using **two neural networks**.
- To maintain the highest level of data collection efficacy, **wireless data transfer behavior has been quantified** to be incorporated in stimulation event marking for AI training use.
- **Varying stimulation parameters**, including amplitude, frequency, pulse width, and stimulation location, produces **predictable muscle response behavior** characterized by unique sensation intensities and locations.
- Using **original stimulation control software**, psychometric data will be recorded during clinical trials to **determine perception thresholds** which can be applied to **future rehabilitative devices**.

Bypass Severed Spinal Connection using Artificial Intelligence

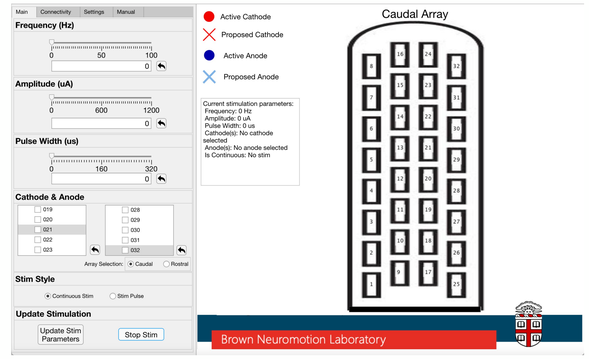


1. Decode descending motor intention in rostral array
2. Look-up inferred caudal array stimulation parameters to match initial motor intention
3. Execute stimulation parameters matching intended motor output on caudal array
4. Decode ascending proprioceptive signals e.g. limb position
5. Look-up inferred rostral array stimulation parameters
6. Execute stimulation parameters matching initial proprioceptive signals on rostral array



Stimulation Control User Interface

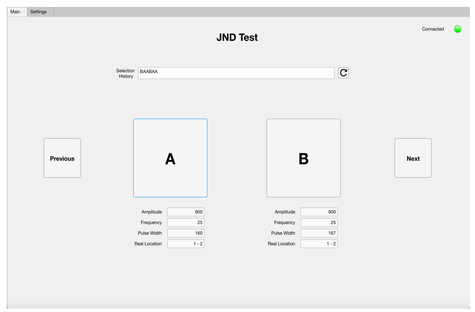
Right: Custom stimulation control user interface used by researcher allows for selection of highly customizable parameter values including stimulation frequency, amplitude, pulse width, location, array selection, stimulation continuity, and in-app parameter ranges, alongside fully integrated IPv4 network connection feature and a server-side message-readback system to ensure individual stimulations are carried out safely.

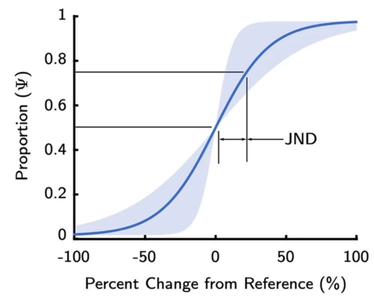


Perception Thresholds & Applications to Future Tech

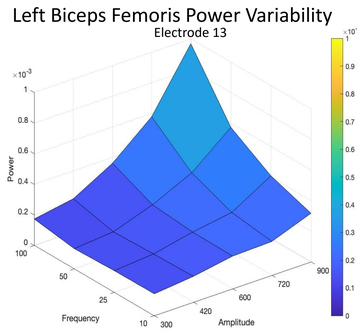
Left: Custom user interface used by researcher to conduct psychometric data collection experiment. Has the ability to test absolute and relative perception thresholds given researcher-inputted stimulation parameter values.

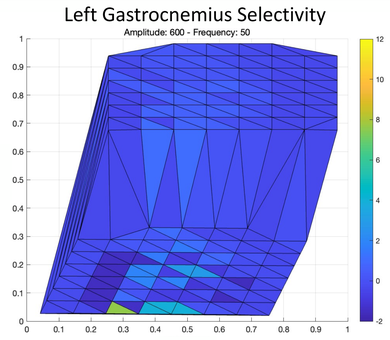
Right: General psychometric curve. After analysis of data collected during clinical trials, we expect to be able to fit this sigmoidal curve to the data with proportion of correct perceptions dependent on the change in a specific stimulation parameter. This data can be used to group specific stimulation parameter combinations that elicit distinct levels of proprioception for use in future neurorehabilitative technology.

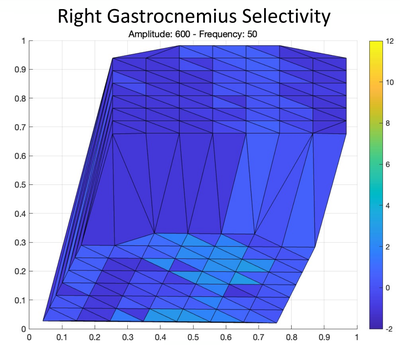




Varying Stimulation Parameters Evokes Selective Muscle Response







Left: Left biceps femoris evoked power output as a function of both amplitude and frequency of electrical stimulation. Increasing amplitude generates a larger population of activated muscle fibers, and increasing frequency causes each individual muscle fiber to fire a greater amount of action potentials over the stimulation duration.
Middle & Right: Selectivity of left and right gastrocnemius over entire electrode array at 600 µA and 50 Hz.

Quantify Bluetooth Performance to Ensure Data Collection Efficacy

Left: Experiment setup diagram. Compared difference in data transfer speeds between wired and wireless connection to Vicon data acquisition software. MATLAB script changes screen color between black and white every second, recorded and transmitted to Vicon via wired photodiode connection. On color change, data of random length (1-19 characters) is sent via Bluetooth to Vicon. Averages of the durations of these transmission trials can be used to improve neural network training.
Middle & Right: Visualizations of Bluetooth performance. Average latency between one- and 19-character data messages differs by less than 3 ms. Average latencies for all data sizes were measured to be less than 9 ms.