



## Supplementary Materials for

### **A neural interface provides long-term stable natural touch perception**

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Materials and Methods

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Fig. S2. Stable electrode impedances across study duration.

Fig. S3. Subject 2 contralateral pressure matching.

Table S1. TAPES Pain Survey data.

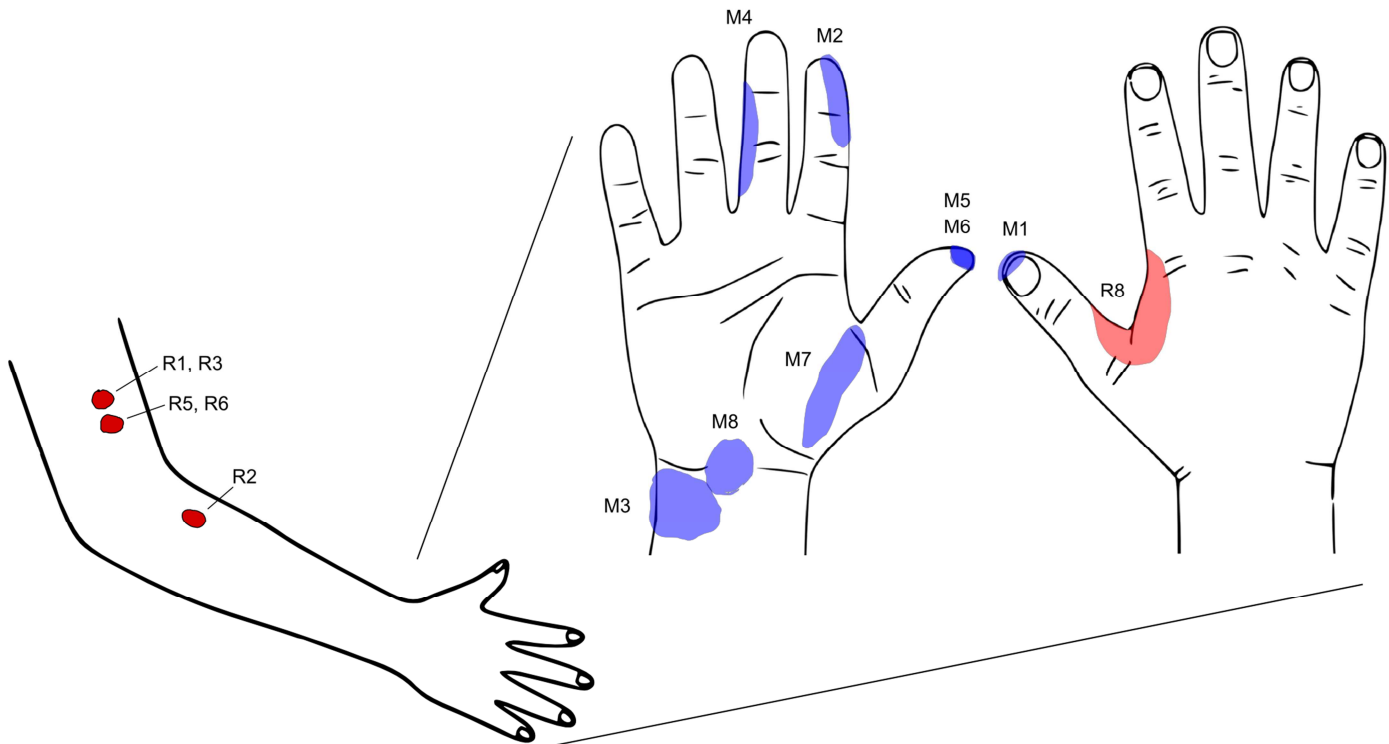
## **Supplemental Material**

### **Materials and Methods**

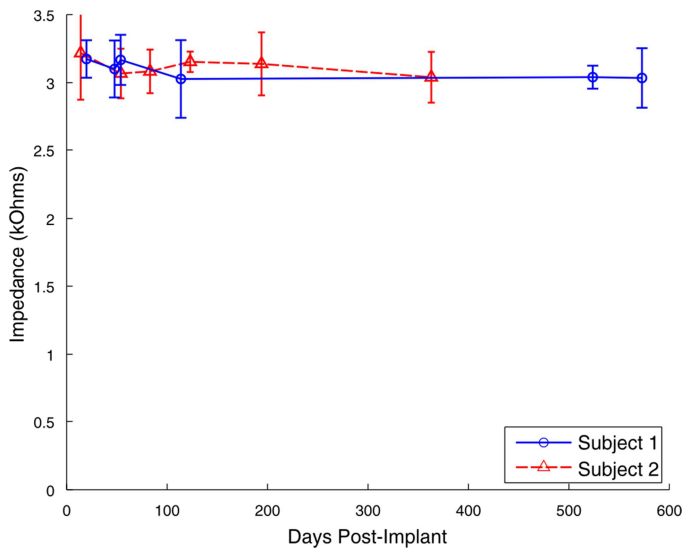
#### **Threshold Detection Method**

We used the Single-Interval Adjustment Matrix, which is an unbiased, adaptive staircase method (30) to determine the sensory perception threshold. We set parameters for a target performance of 50% with true stimulation provided 50% of the time. The threshold search stopped after 12-16 reversals of perceived and not perceived sensation. Stimulation was a 1 sec train and repeated if requested by the subject. Stimulation frequency was constant at 20 Hz. To prevent overstimulation, we increment stimulation pulse amplitude (PA) and pulse width (PW) by 0.1 mA and 10  $\mu$ s steps, respectively, until the rough threshold was determined. Then, we hold PA at constant 0.1 mA below the rough threshold and apply the adaptive staircase method to determine a precise PW threshold with 1  $\mu$ s resolution.

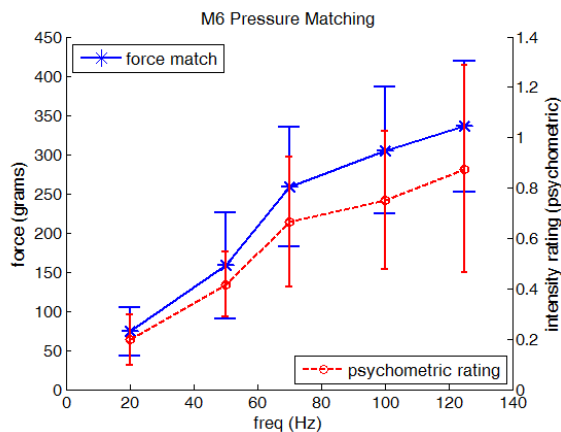
## Figures and Tables



**Figure S1. Subject 2 perceptual locations at near-threshold stimulation levels.** Cuff electrodes were selective, even though subject 2 was implanted in the upper arm at a much more proximal location than subject 1. This section of the nerve has a combination of both motor and sensory fibers and includes sensory fibers innervating the forearm and upper arm. Sensory response was actually elicited from 14 of 16 available contacts, but some of these were on the residual limb which we excluded from the report. We focused on the 9 of 16 contacts which produces sensation on the perceived hand. This is quite remarkable given the proximal location of the electrodes which demonstrates the generalizability of the multi-contact, extraneural interface approach.



**Figure S2. Stable electrode impedances across study duration.** Impedances were measured across electrode channel pairs by providing a 0.3 mA and 50  $\mu$ s stimulus pulse train at 20 Hz. Impedance was calculated by measuring the peak voltage drop. In both subjects, linear regression suggests impedances did not change significantly (subject 2, ANOVA,  $p = 0.271$ ) or exhibited a decrease (subject 1, ANOVA,  $p = 0.009$ ) throughout the study duration.



**Figure S3. Subject 2 contralateral pressure matching.** In subject 2, contralateral pressure matching also indicated frequency can modulate intensity of constant pressure sensation ( $N = 25$ ,  $R^2 = 0.663$ , linear regression  $p < 0.001$ ). The subject was provided SSO modulation with IPI set to 50, 20, 14.3, 10 or 8 ms (20, 50, 70, 100 or 125 Hz) on channel M6 and asked to match the perceived pressure (blue) with his contralateral hand. Perceived constant pressure intensity was on the order of 0-500 grams ( $< 1$  lb) similar to subject 1. We also requested the subject to rate the intensity (red) on an open-scale, which showed surprising similar trends with measured force data.

		Weeks post-implant					
		Pre-Implant	23	65	68	72	75
<b>Subject 1</b>	Episodes per week	2	5	0	0	0	0
	Ave length of episode	30 min	2hrs	-	-	-	-
	Ave level of pain	mild	discomforting	-	-	-	-
	Interference with lifestyle	not at all	not at all	-	-	-	-
		Weeks post-implant					
		Pre-Implant	34	37			
<b>Subject 2</b>	Episodes per week	2 per month	0	0			
	Ave length of episode	1 sec	-	-			
	Ave level of pain	excruciating	-	-			
	interference with lifestyle	not at all	-	-			

**Table S1.** TAPES Pain Survey data. The pain survey from the Trinity Amputation and Prosthesis Experience Scales (TAPES) was administered throughout the study, demonstrating a reduction of phantom pain in both subjects. There may be an association with phantom pain reduction and the provision of natural sensory feedback without paresthesia.