Efficacy of high-frequency stimuli in tactile peripheral nerve*

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I. Introduction

Tactile experience arises from specialised afferent neurons, each of which can send hundreds of impulses per second in complex temporal patterns. Electrical nerve stimulation offers an alternate method to activate these neurons, and is the key operating principle of most sensory hand prostheses. However, recent evidence from electrical stimulation of nerve stumps in human hand amputees, shows that the subjects are unable to discriminate stimulus frequencies for rates above 50 Hz [1]. This is surprising, as healthy subjects can discriminate frequencies of mechanical skin vibrations up to several hundred Hz. We have therefore measured human discrimination of both low and high frequencies delivered by electrical and pulsatile mechanical stimulation, using two different intensities as a confounder to mask any intensity cues in making the frequency judgement.

II. Procedures

Twelve healthy subjects (ages 18-44) of both sexes with no known history and clinical presentations of neurological disorders were recruited for this study. All participants provided written consent prior to experimentation and the experimental protocols were approved by the UNSW Human Research Ethics Committee (HC16245).

The apparatus used were those described by Ng et al. (2022) [2]. Using a two-alternative forced choice (2AFC) paradigm, participants were presented with two sequential pulse trains comprised of the test and comparison frequency, in random order, and were asked to make a forced choice of which stimulus possessed a higher frequency. The 1000 ms pulse trains were separated by 500 ms, delivered to the index finger. Mechanical and electrical stimulation parameters are given in Table I and Table II respectively.

Psychometric curves were fitted to subject data and a coefficient of determination determined.

Table 1: Parameters of the mechanical stimulation experimental pattern.

	Test Frequency (Hz)	Test Amplitude (μm)	Comparison Frequencies (Hz)	Comparison Amplitude (μm)	Repeats	Total Trials
Stronger Comparison	50	70	25, 30, 40, 60, 75, 100	100	20	120
	100	70	50, 70, 85, 125, 150, 200	100	20	120
	150	70	75, 100, 125, 175, 200, 300	100	20	120
Weaker Comparison	50	100	25, 30, 40, 60, 75, 100	70	20	120
	100	100	50, 70, 85, 125, 150, 200	70	20	120
	150	100	75, 100, 125, 175, 200, 300	70	20	120

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Table 2: Parameters of the electrical stimulation experimental pattern.

	Test Frequency (Hz)	Test Pulse Width (μs)	Comparison Frequencies (Hz)	Comparison Pulse Width (μs)	Repeats	Total Trials
Stronger Comparison	50	100	25, 30, 40, 60, 75, 100	130	20	120
	100	100	50, 70, 85, 125, 150, 200	130	20	120
	150	100	75, 100, 125, 175, 200, 300	130	20	120
Weaker Comparison	50	130	25, 30, 40, 60, 75, 100	100	20	120
	100	130	50, 70, 85, 125, 150, 200	100	20	120
	150	130	75, 100, 125, 175, 200, 300	100	20	120

III. Results

Subjects were tested for their ability to discriminate frequency at 50, 100, and 150 Hz using both mechanical and electrical stimulation. Subject ability to perform the task was judged on the basis of having a psychometric curve that crossed 50% and on the R^2 fit which is shown in Fig.1. Subjects were considered able to perform the frequency discrimination task for the mechanical or electrical stimuli, if their R^2 was at least 0.75 for both the strong and weak comparison conditions. For mechanical stimulation, all 12 subjects were able to perform the task at a test frequency of 50 Hz (R^2=0.95 ± 0.05, mean ± SD). At 100 Hz, 10 subjects could perform the task (0.94 ± 0.06) and at 150 Hz, 9 subjects could perform the task (0.90 ± 0.06). For electrical stimulation, at a test frequency of 50 Hz, 11 subjects could perform the task (mean R^2=0.91 ± 0.06) and at 100 Hz, 1 subject could perform the task (R^2=0.97). However, at 150 Hz, no subjects were able to perform the electrical frequency discrimination task for both comparison conditions.

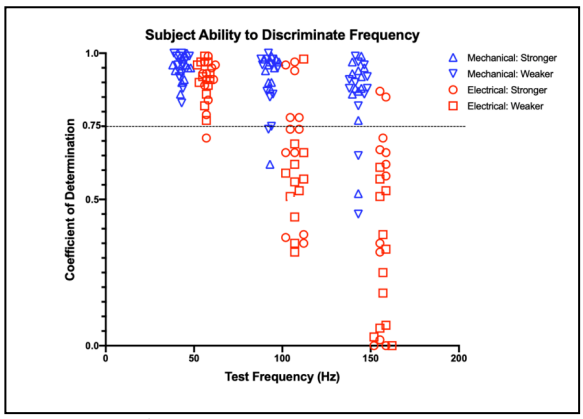

Figure 1. Subject R^2 values for electrical and mechanical stimulation show electrical is less efficient regardless of direction of intensity confounder.

References

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