The Con-Tactor: A Novel Tactile Stimulator that Makes and Breaks Contact with the Skin

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ABSTRACT

Haptic devices called ***tactors*** are used in consumer and research equipment to simulate the sense of touch with vibration. Issues with present tactors include difficulty for users to distinguish temporal sequences and excess residual vibration of the skin in contact with the device. The goal of our work is to improve traditional tactors and develop a device for quantifiable diagnosis of peripheral neuropathy. We have designed a novel haptic stimulator that makes and breaks contact with the skin, thereby creating tactile sensations in the form of repeated discrete onsets and offsets. Based on preliminary testing, our device, ***the Con-Tactor***, shows potential as a stimulation device for research into tactile sensation of low-intensity impact and diagnostic point localization tests for neurological disorders.

BACKGROUND

Peripheral Neuropathy

- Medical condition resulting in numbness, pain, or weakness from **nerve damage**
- **40 million patients** in the US [1]
- Typically diagnosed by **qualitative** physical examinations (Fig. 1) and skin biopsies which are often performed **after permanent nerve damage has already occurred** [2]
- Currently, there are **no quantifiable, noninvasive** assessment devices

Fig. 1: Physical examination for peripheral neuropathy in the clinical setting

Tactors

- **Vibration devices** used to simulate the sense of touch through **haptic feedback** (Fig. 2), for example:
  - **FingerSight:** a technology developed in the VIA lab that uses a video camera to communicate with tactors mounted on the finger to guide a visually impaired user towards a designated target [3]
- **Limitations** of tactors:
  - Difficult for users to distinguish temporal pattern sequences
  - Residual vibration and decreased user sensitivity from constant skin contact [4]

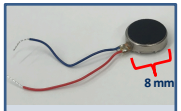

Fig. 2: A classical tactor used in devices like FingerSight to stimulate tactile perception

PURPOSE

By allowing the skin to recover ~~in~~ between contact cycles, we believe a device that repeatedly makes and breaks contact with the skin will allow us to overcome the limitations of traditional tactors and assess a new modality of haptic stimulation. We hope to accomplish the following:

1. **Evaluate the psychophysics of low-intensity impact**
2. **Provide an alternative to traditional tactors**
3. **Develop a robust method for repeatable, early, and quantifiable diagnosis of peripheral neuropathy**

METHODS

Device Description & Design

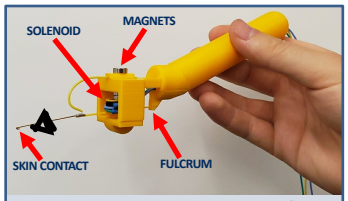

Fig. 3: The Con-Tactor designed as a hand-held tool for application of the oscillating tip to various locations on the skin

- Device is designed as a **third-class lever** with a gold-plated skin contact that uses electrical conductivity between the device and skin to detect contact with the patient (Fig. 3)
- **Cantilever design** maximizes vertical displacement
- **Solenoid electromagnet** used to move skin contact up and down
- Current controlled by **Arduino microprocessor** and custom **linear amplifier circuit** capable of producing positive and negative currents

Calibration & Classification of Device

- Force measurements were recorded with a mass scale for vertical displacement distances of the skin contact
- Cylindrical spacers were used to displace the skin contact a designated distance from its neutral position
- Skin contact functions as a classical spring, representing **Hooke's Law**
  - **k = 0.0032 N/mm**

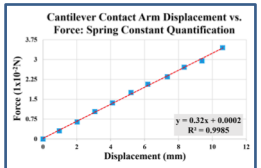

Fig. 4: Linear relationship of vertical displacement versus force for the skin contact cantilever

Preliminary Testing

- In-house testing performed on the **thenar eminence** at the base of the thumb
- Contact arm position was adjusted using a **calibration algorithm** to ensure proper displacement such that the skin contact makes and breaks contact with the patient's skin during testing
- Calibration algorithm brings skin contact to an identical distance from the skin for each test

Fig. 5: Initial testing of the Con-Tactor at driving frequencies ranging from 1–40 Hz

RESULTS

Using the Con-tactor to repeatedly make and break contact with the skin of the thenar eminence produced a sensation easily perceived by users at driving frequencies from 1–40 Hz. Mechanical resonance of the skin contact cantilever was significant, maximal at a driving frequency of 33 Hz (+/-2 Hz), yielding an approximate displacement amplitude of 1 cm. Placing 1.5 V DC across the solenoid resulted in a maximum force of 0.0042 N (Fig. 6). Generation of a square wave voltage input to the solenoid showed the largest displacement of the skin contact when compared to other waveforms including ramps, sinusoids, and triangles. ~~The mechanical elasticity of the skin contact cantilever contributed significantly to the vertical displacement, particularly at the resonant frequency range.~~

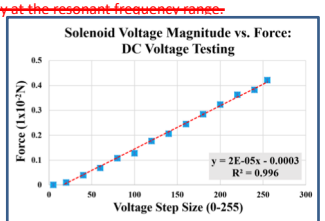

Fig. 6: Linear relationship of DC voltage versus force at voltage magnitudes ranging from 0 – 1.5 V

CONCLUSION & FUTURE DIRECTIONS

The Con-Tactor prototype provides the necessary displacement of the skin contact and force imparted on the user to evaluate the tactile perception of making and breaking contact with the skin. Square wave voltage inputs at frequencies ranging from 1–40 Hz and coil voltages in the range of ±1.5 V optimize the functionality of the present design for creating repeated low-intensity impacts on the skin. When compared to traditional tactors, the Con-Tactor functions at lower driving frequencies and appears to serve as an effective alerting device. We are currently designing experiments to perform free magnitude estimation with the device to characterize how perceptual intensity varies with driving frequency and skin site. Potential clinical applications include quantifying the amount of nerve fiber loss in patients with peripheral neuropathy.

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ACKNOWLEDGMENTS

Funded through the Swanson School of Engineering REU, NSF grant IIS-1518630, and the Center for Medical Innovation (CMI) at the University of Pittsburgh.