Grasping at Illusions: Stimulating the skin to make you think your fingers are moving

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BACKGROUND

Sensory feedback from receptors in the muscles, skin, and joints provides crucial information about limb movement. This "movement sense", also known as **kinesthesia**, is believed to be primarily informed by muscle receptors (i.e., muscle spindles). When we move, these muscle spindles discharge as the muscles lengthen. Thus, most kinesthetic research has focused on them. Receptors in the skin (i.e., cutaneous receptors) also discharge when we move, although their role in kinesthesia remains less clear. Therefore, this project aims to **investigate the role of cutaneous receptors in kinesthesia** by exploring the effect of electrical stimulation on perceived movements.

Figure 1. Visual depiction of the role of cutaneous receptors kinesthesia.

HYPOTHESES:

1) Electrical stimulation of axons from cutaneous receptors will induce perceived finger flexion;

2) Increasing both the frequency & intensity together will produce the largest illusory movements, compared to increasing frequency or intensity alone.

METHODS

- Participants (n=18) seated with hands relaxed over a stable surface
- View of the right hand blocked by a cardboard divider
- Electrical stimulation applied to the right, "test" hand to stimulate axons from cutaneous receptors and mimic their discharge during movement
- If they perceived movement in their right hand, they were instructed to mimic the movement with the left, "matching" hand
- Perceived ("illusory") movements were quantified using motion capture

Figure 2. Left) Participant setup. Electrodes were placed over the Superficial Branch of the Radial Nerve on the right hand with the cathode (black) placed proximal to the anode (red). Reflective markers were placed on the joints of the index fingers of both hands for motion capture. **Right)** Participant's left hand relaxed while stimulation is off, and mimicking the movement felt by the right hand with stimulation on.

ELECTRICAL STIMULATION (ES)

- ES was delivered in 3 patterns (Frequency, Intensity, Combined) and a "Sham" trial
- Frequency or Intensity increased then decreased sinusoidally over 5 seconds (Figure 3)
- 5 cycles of stimulation per trial, each trial was presented 3 times in a random order
- "Sham" trial was included to verify participants' perception of movement due to ES

1. **Frequency**: cycled between 55-250 Hz; intensity at perceptual threshold (PT)
   (increased, then decreased, **to mimic changes in discharge frequency of receptors during finger movements**)
2. **Intensity:** 1-2x perceptual threshold (e.g., when the participant first felt the stimulation pulses); frequency constant at 55 Hz
   (increased, then decreased, **to mimic changes in the number of receptors activated during finger movements**)
3. **Combined:** both frequency & intensity increase and decrease together
4. **"Sham"**: frequency held at 55 Hz; intensity held at PT

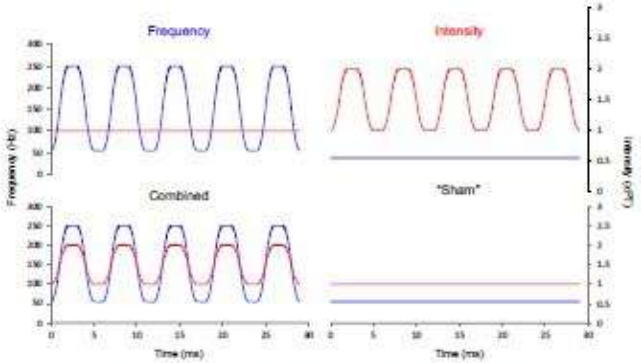

Figure 3. Visual representations of the electrical stimulation trials delivered.

RESULTS

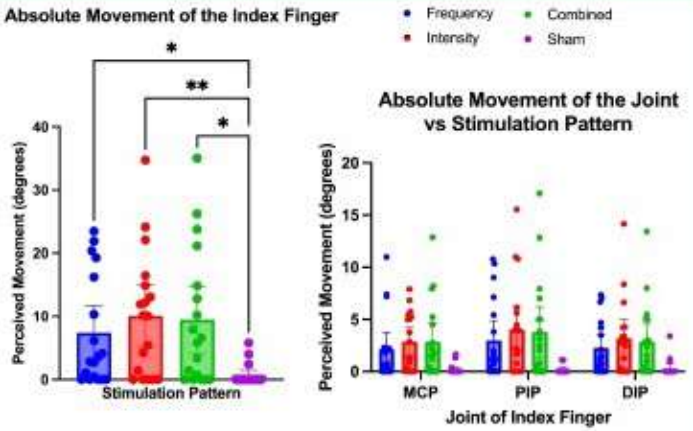

Figure 5. Absolute values of the individual joints of the index finger summed together as the net movement of the finger. Group data; bars are the mean ± 95% confidence interval. *p <0.05,** p<0.001

Figure 6. Analysis of the absolute values of the perceived movements of the joints of the index finger and the stimulation patterns. Bars represent the mean ± the standard deviation. MCP – Metacarpophalangeal joint; PIP – Proximal interphalangeal joint; DIP – Distal interphalangeal joint.

RESULTS

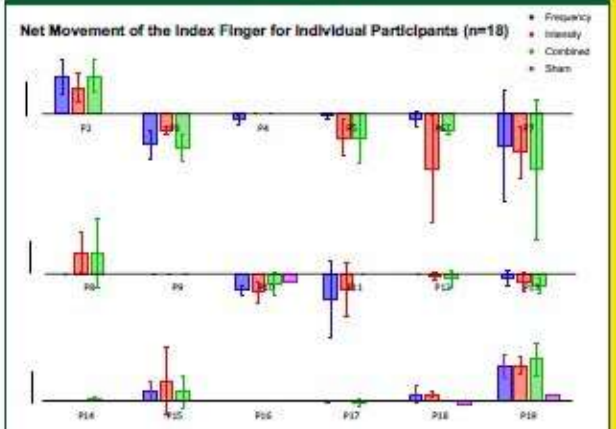

Figure 4. Single subject participant data. Positive numbers represent extension, negative numbers represent flexion. Bars depict the means ± standard deviations. Scale bar is 20 degrees.

Preliminary Findings

- 16/18 (89%) of participants perceived movement in at least one trial.
- 13/18 (72%) of participants perceived movement in the index finger.
- 10/18 (56%) of participant perceived flexion of the index finger.

CONCLUSIONS/LIMITATIONS

1. When electrical stimulation was applied to the skin of the hand, almost 90% of participants thought their fingers were moving, when they were not. **The skin plays a role in the perception of finger movements (kinesthesia)**
2. The size of the illusory movements was not different when increasing stimulation intensity, frequency, or increasing both together. **To produce illusions of movement, changing stimulation intensity and frequency are equally effective.**
3. This work adds to our understanding of how humans perceive movement and has applications for prosthetics, rehabilitation, and virtual reality.

Limitation:
In only ~50% of participants were movements in the predicted direction. Difficult to assess how accurately participants "matched" movements.

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