Developing a Human-in-the-Loop Controller for Haptic Feedback

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INTRODUCTION

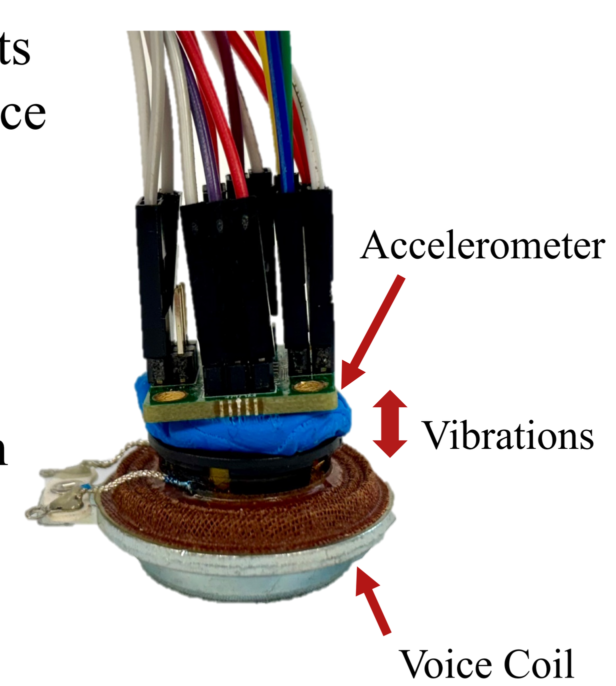
- **Wearable haptic systems** can help guide movement and deliver feedback [1].
- Most current devices use **open-loop systems** (predefined haptic patterns).
- These don't account for user motion—especially during **dynamic activities** like walking [2], [3].

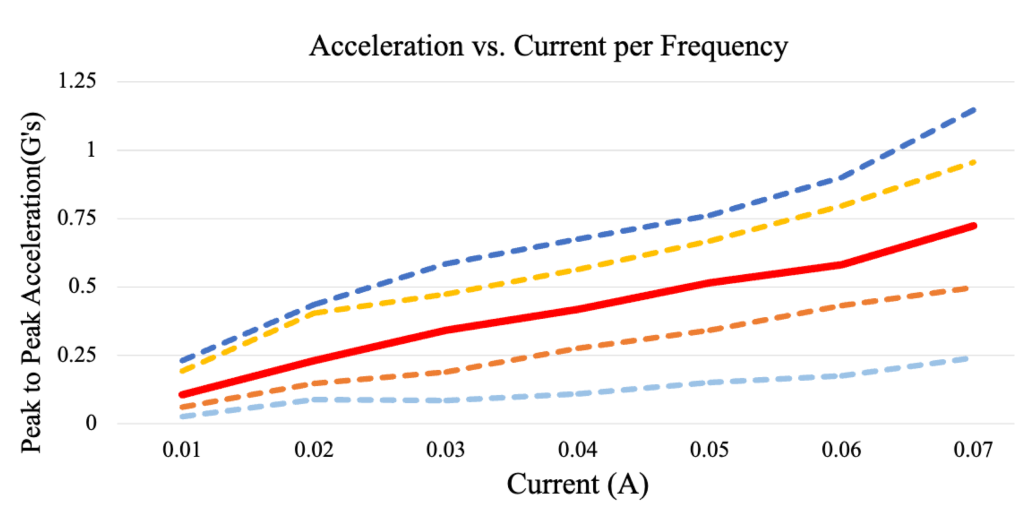
OBJECTIVE

- Design and build a **wearable platform** for delivering wrist-based haptic cues.
- Run **perception threshold experiments** while subjects are walking to characterize change in haptic perception during walking.
- Use understanding of haptic perception during walking to create **a human-in-the-loop controller**.

ACTUATOR CHARACTERIZATION

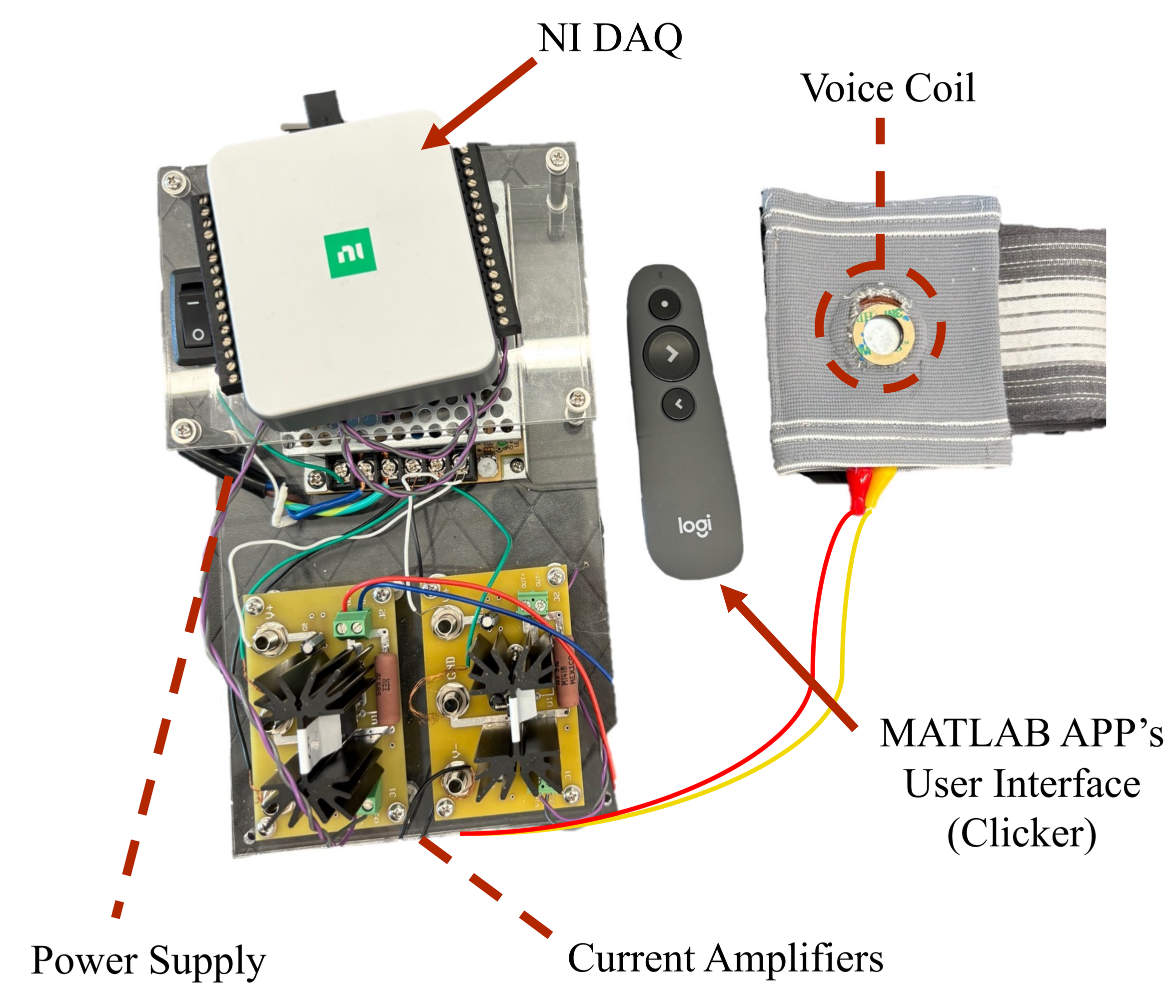
- A Tectonic Elements TEAX19C01-8 voice coil actuator was driven with sine waves of varying amplitudes (A).
- Output acceleration (G's) was recorded with an onboard accelerometer.





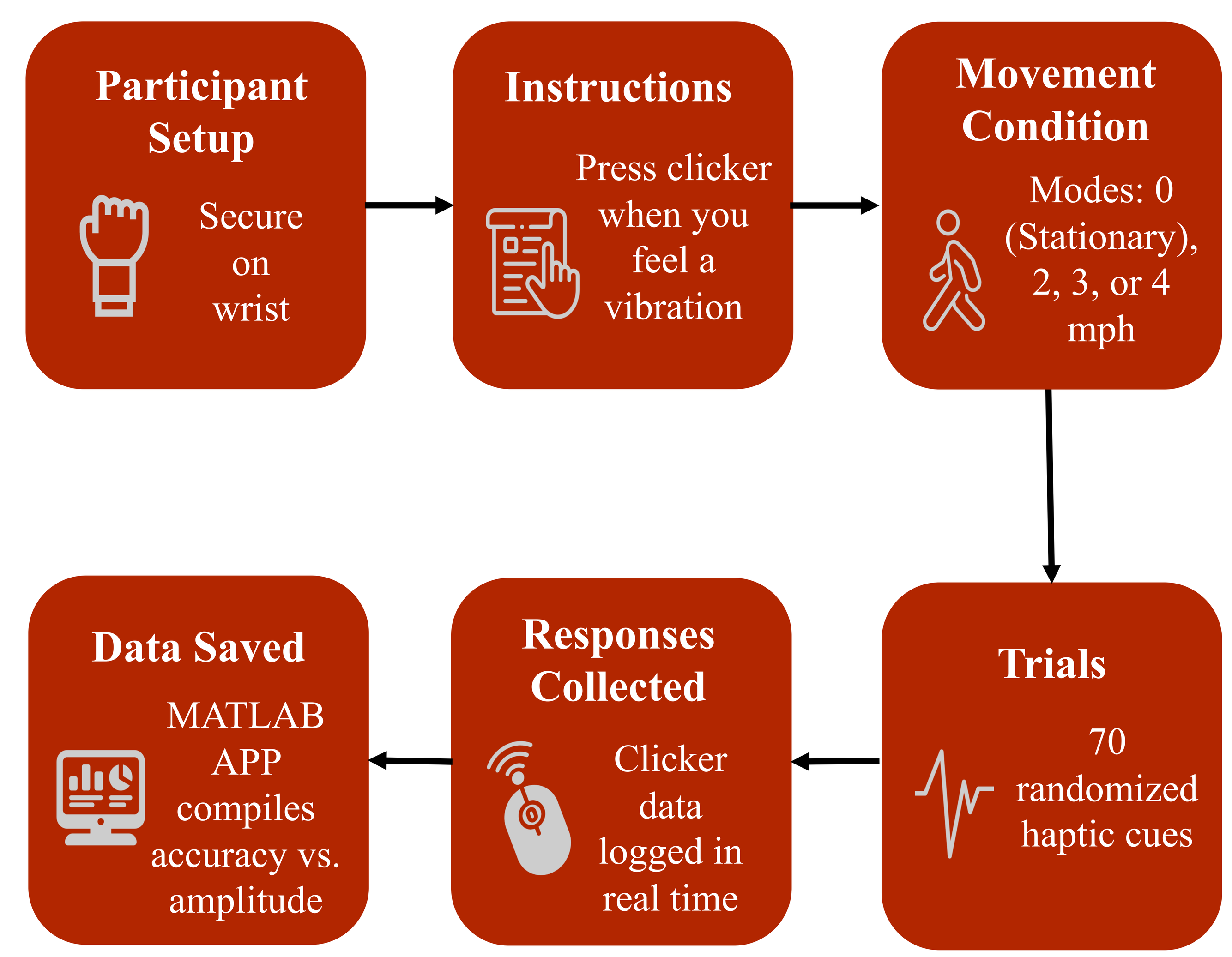
At **200 Hz** the voice coil exhibited a strong response, high signal-to-noise ratio, and consistent linearity across the amplitude range.

SYSTEM OVERVIEW



- Custom **wrist-worn device** with a voice coil actuator.
- Controlled via **NI DAQ + MATLAB App** for frequency and current modulation.
- Subjects respond using a **wireless clicker**.
- Setup allows for **easy parameter sweeps** and **real-time logging** of responses.

HUMAN SUBJECT STUDY DESIGN



Wrist-worn system secured using Velcro band

Participants: 3 females, ages 20–23

Movement Conditions: 0 (Stationary), 2, 3 and 4 mph

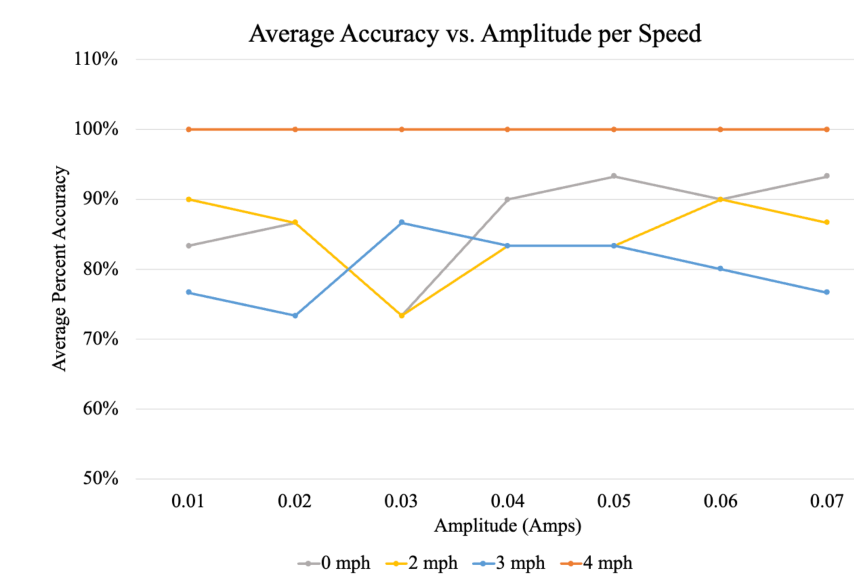
Amplitudes: 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07 A

Repetitions: 10 randomized of repetitions of each amplitude for a total of 70 trials

Time Interval Between Cues: Randomized from 3-6 seconds

RESULTS

- Perception accuracy was **high (≥83%)** for currents ≥ 0.04 A.
- Perception **improves with increased walking speed**, possibly due to greater sensory engagement and attentional demand during faster movement.
- Suggests **0.04 A** is a reliable **baseline threshold** across dynamic conditions.



DISCUSSION & FUTURE WORK

A stimulus of 0.05 A at 200 Hz was effective across conditions, with consistent perceptual thresholds observed during both stillness and movement—supporting potential for closed-loop control. Future directions include:

- integrating inertial sensors for real-time motion detection
- closing the loop by adapting feedback to user movement
- expanding testing to broader populations
- applying findings to real-world scenarios such as gait correction, rehabilitation cues, and assistive technologies.

REFERENCES & ACKNOWLEDGEMENTS

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[2] K. T. Yoshida*, J. X. Kiernan* *et al.*, "Cognitive and Physical Activities Impair Perception of Smartphone Vibrations," IEEE Trans. Haptics, vol. 16, no. 4, pp. 672–679, 2023.

[3] C. G. Welker *et al.*, "Human Perception of Wrist Flexion and Extension Torque During Upper and Lower Extremity Movement," IEEE Trans. Haptics, vol. 15, no. 4, pp. 741–752, 2022.

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