**Introduction**

**Material & Methods**

**Haptic Devices**

For this study, we created two identical force-controlled wearable haptic devices that apply localized pressure on the forearm. The haptic devices apply stimuli as per given force commands and provide real-time measurements on force and displacement of the skin. Each device is comprised of a pressure stimulator and electronics module.

The key component of the pressure stimulator is a small, high-precision position-controlled linear actuator with position feedback (MightyZap xxxx) in a rigid plastic enclosure. The actuator in its enclosure is positioned perpendicularly to the forearm, where the actuator’s shaft extends directly into the arm and creates a pressure sensation.

The actuator shaft is equipped with a cylindrical tactor and custom enclosure for a low-profile capacitive force Sensor (SingleTact, dia. 15 mm and force range 0-45 N), allowing for real-time force feedback. We utilize the force feedback to implement closed loop force control using a kPID controller, where the controller adjusts the actuator’s position to generate the commanded force stimulus.

The pressure stimulator fastens to the forearm with a flexible plastic interface and hook-and-loop strap. It also has foam padding to diffuse the opposing force from the strap and ensure the wearer receives a localized pressure sensation instead of a squeezing sensation.

The second part of the wearable haptic device is its electronics module. The electronics module is an embedded system that is responsible for numerous tasks: it directs the pressure stimulator’s linear actuator, reads force and position data, implements force control, parses new force commands, executes calibration and runtime modes, and integrates with custom software to save data and run user studies.

The electronics module distinguishes itself from other systems [cite] [cite]as an entirely wearable unit that is not encumbered or tethered by additional

that clips conveniently to the pressure stimulator via magnetic

The electronics module consists of an ARM-M microcontroller (Teensy 4.0), bidirectional buffer for the UART connection with the linear actuator, the accompanying force sensor’s I2C chip, and Bluetooth LE chip, and 12V lithium ion battery.

The microcontroller is the main showrunner with a custom firmware

The electronics module

distinguishes itself as wholly wearable and not tethered

microcontroller bidirectional buffer for uart with position feedback, 2way uart BLE chip, , i2c force sensor chip,powered by lipo or the wall source

powerhungry

Calibration mode and runtime

Magnetic connector to straps

**Bluetooth base software**

**Experiments 1**

**Experiment 2**

**Experiment 3**

* disrupt dichotomy of high precision grounded set-up and novel wearables with limited sensing and open loop feedback
* towards “in the wild” measurements
* modular
* untethered for free, unrestricted motion
* not aiming to replace the ultra high precision , but demonstrates that we can do high fidelity perception studies in a wearable context with robust sensing and closed-loop feedback
* allows us to quantify the specific haptic and perceptual experiences that are unique to a wearable context
  + ex. wearables will have some opposing force
* though our measurements are a product of our specific device design / design choices, this follows the precedence of a wealth of previous work that has generated experimental setup-specific measurements alongside compelling, transcendent insights on perception. our work elucidates a valuable perceptual phenomenon and
* shifting away from tethered laboratory setups limited by cumbersome sizes air sources and high power systems and towards towards a realizable system for real-world applications
* social relationship with devices, perception of how it looks

<https://link.springer.com/chapter/10.1007/978-3-540-73111-5_56>

**Medical Device and Equipment Design: Usability Engineering and Ergonomics**

edited by Michael E. Wiklund

* perception will vary in a in-the-wild context with additional sensory distractions (kyles papers). step towards developing hardware for those applications