NRI: FND: COLLAB:
Intuitive, Wearable Haptic Devices for Communication with Ubiquitous Robots

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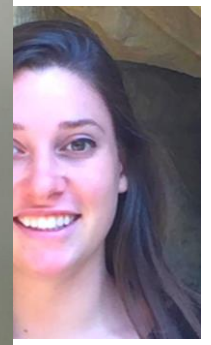


Cara Nunez

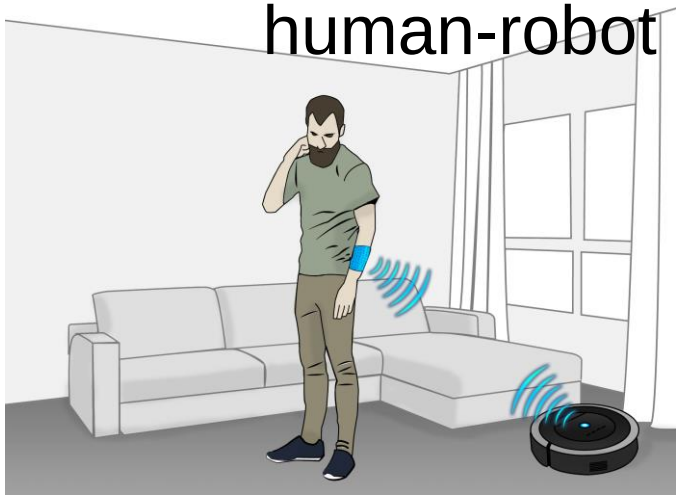
Kyle Yoshida

Challenge: How can we make haptic devices intuitive, unobtrusive, and wearable?

human-human

human-agent

human-robot

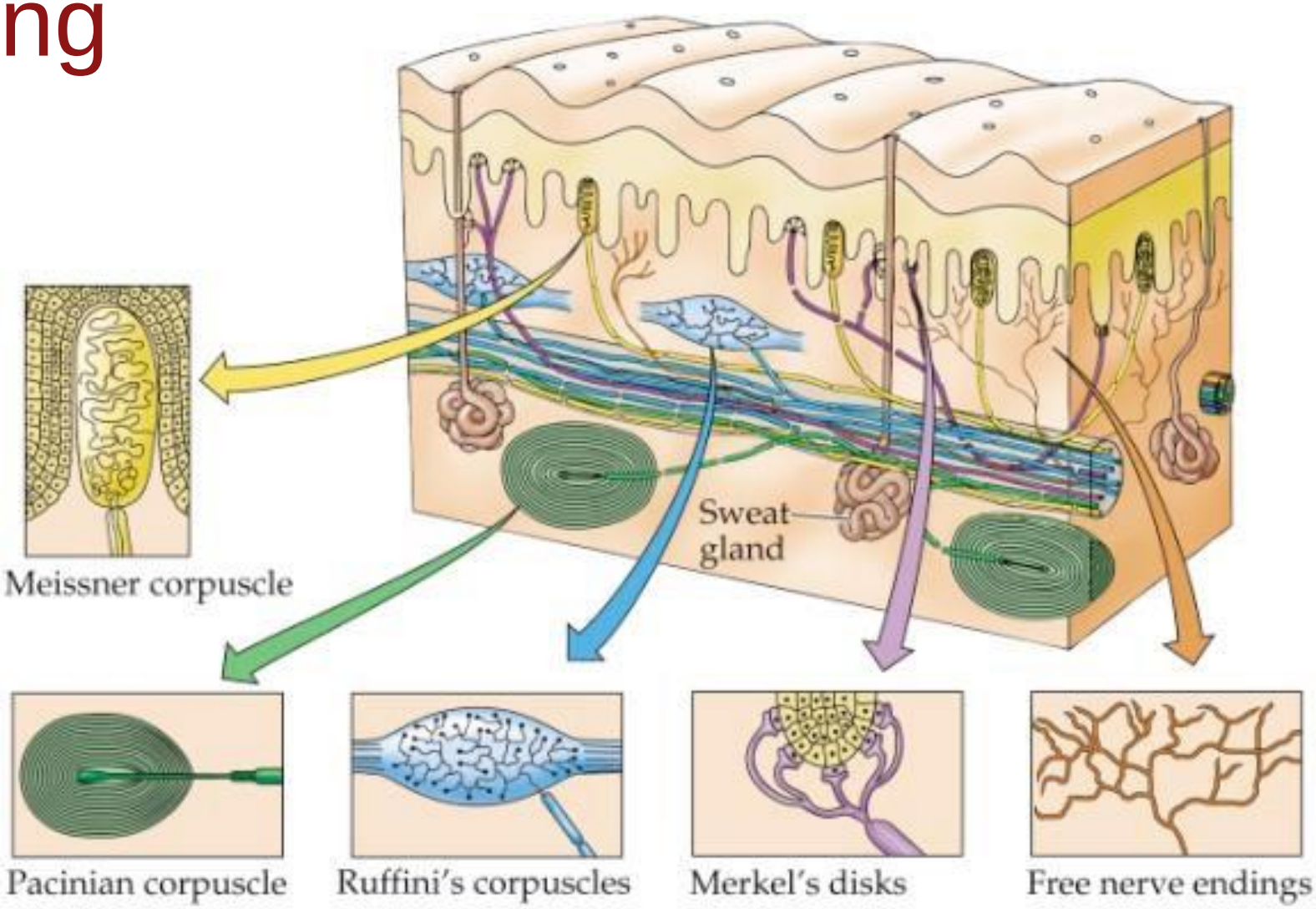


Images courtesy Even Pezent

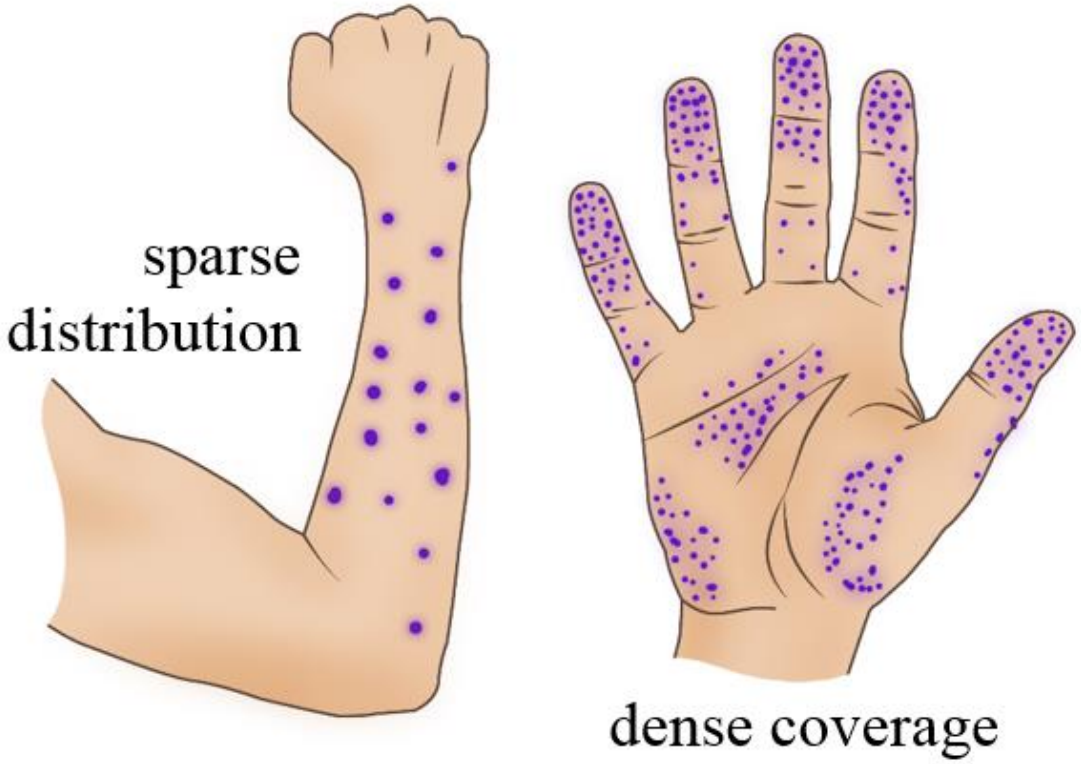
Cutaneous sensing

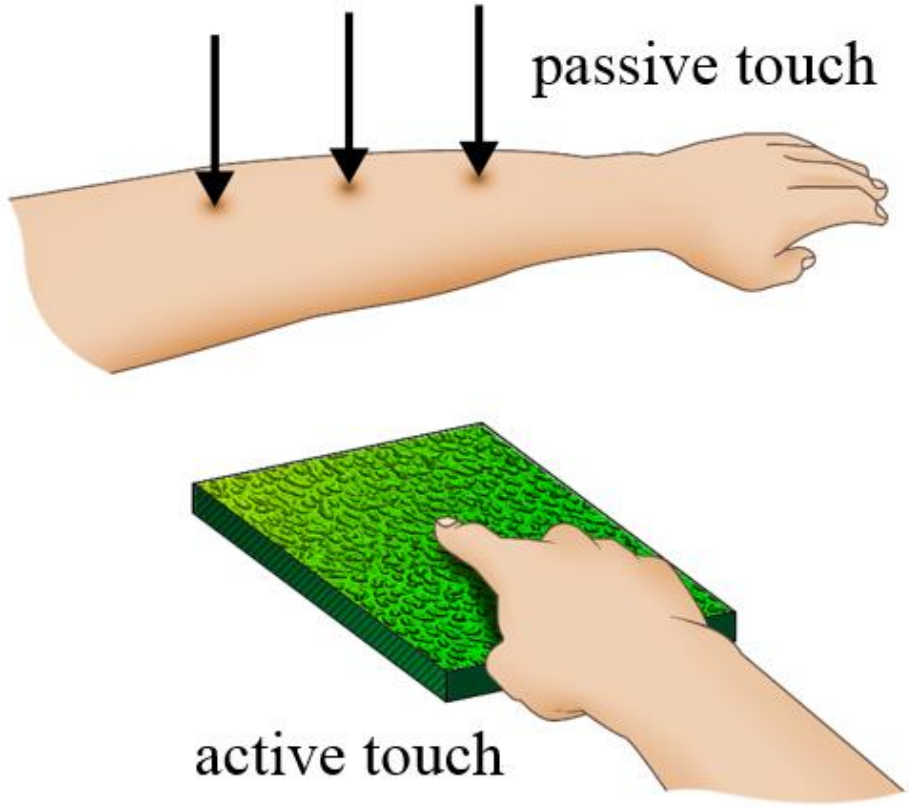
Mechanoreceptors in the skin vary by:

- Density / spatial distribution
- Response to stimuli frequency
- Type of skin (glabrous vs. hairy)



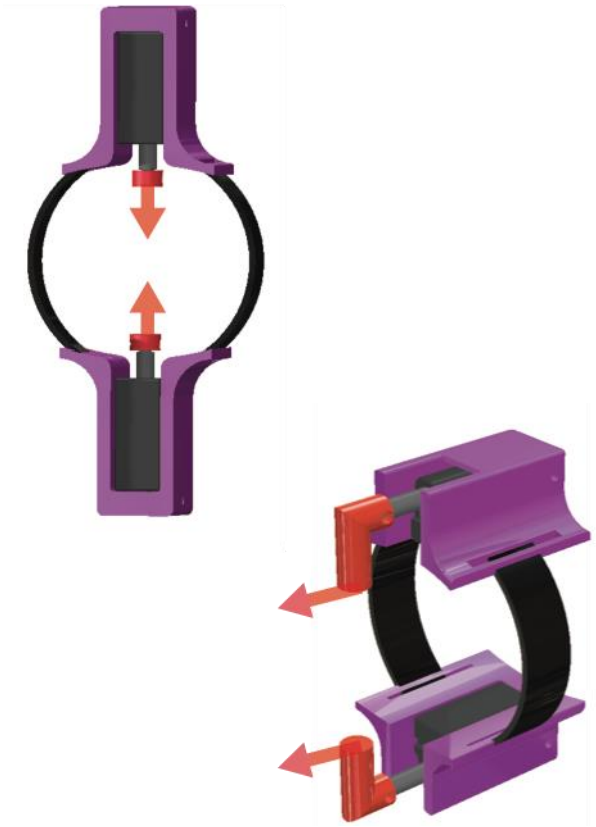
Arms vs. Fingertips

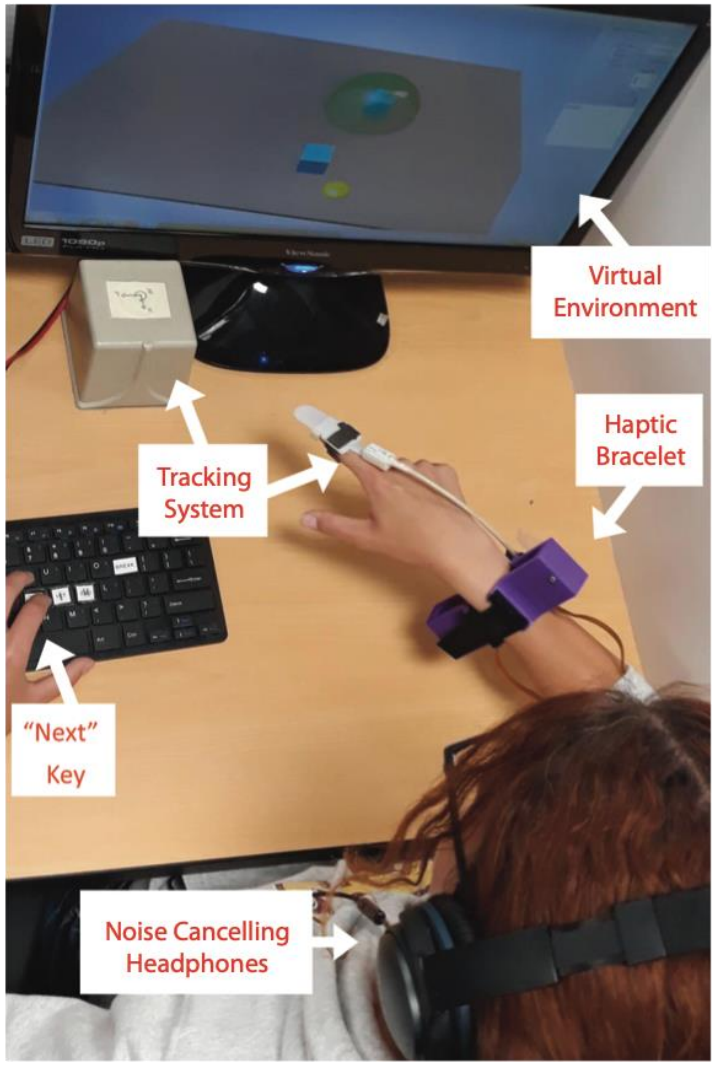




Images courtesy Even Pezent

Moving away from the fingertips

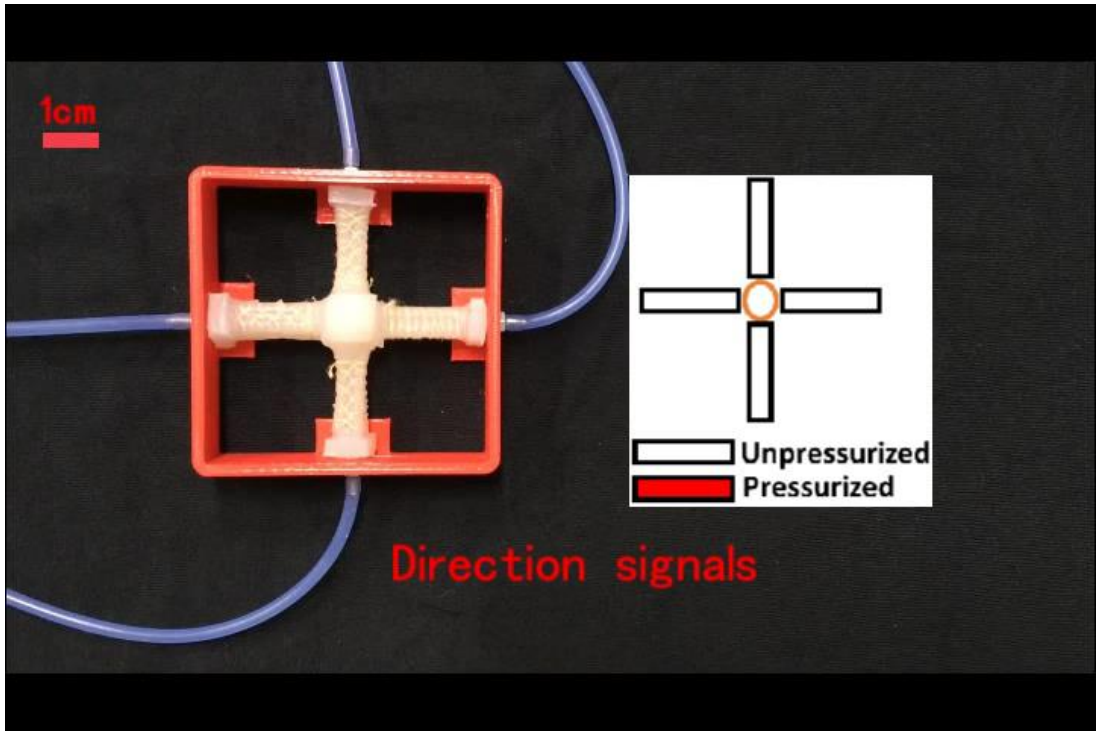




Participants can still identify virtual object properties!

Soft wearable haptics

single point, multiple directions



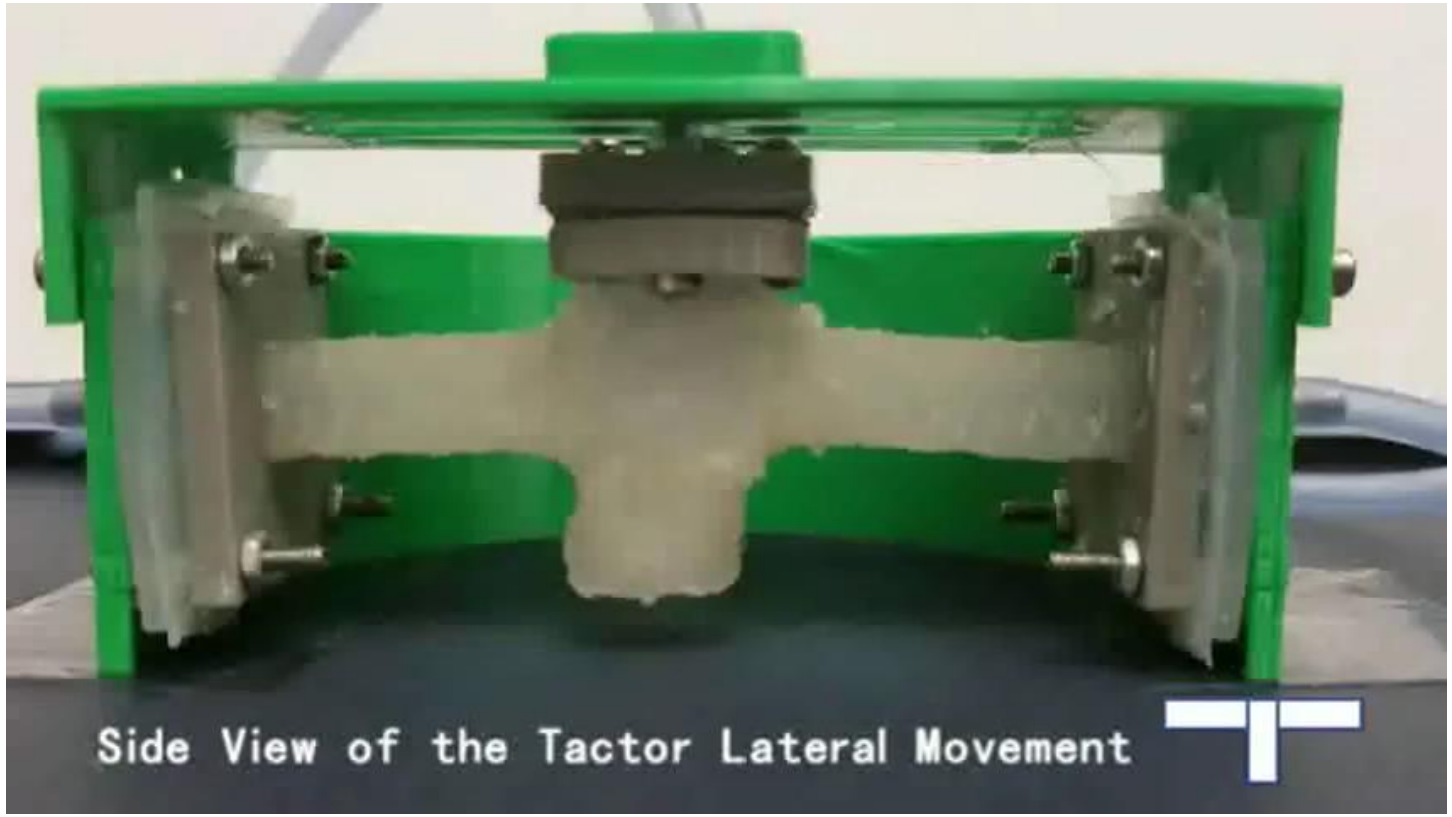
Kanjanappas et al. 2019

multiple points, single direction

Agharese et al. 2018

Soft Wearable Devices

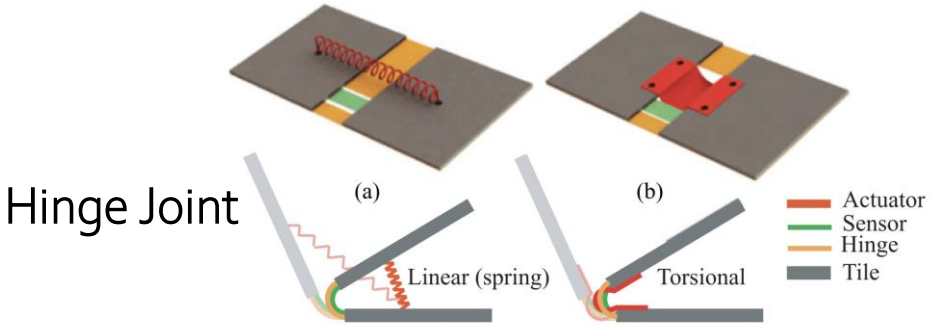
single point, multiple directions



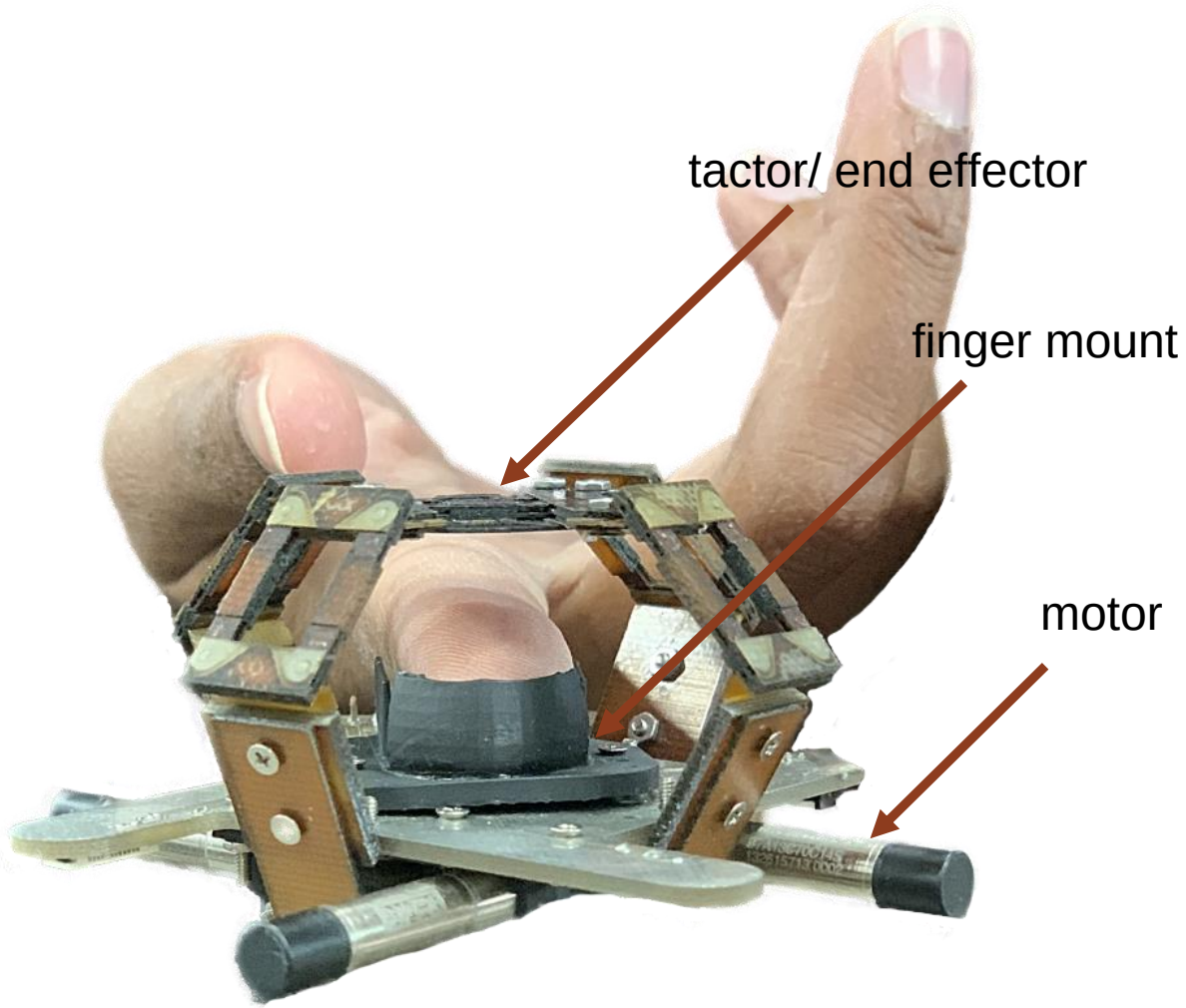
Yoshida, et al. 2019

4-DOF Origami Haptic Device

- Applies normal, shear and torsion feedback
- Layered manufacturing techniques like those in circuit design

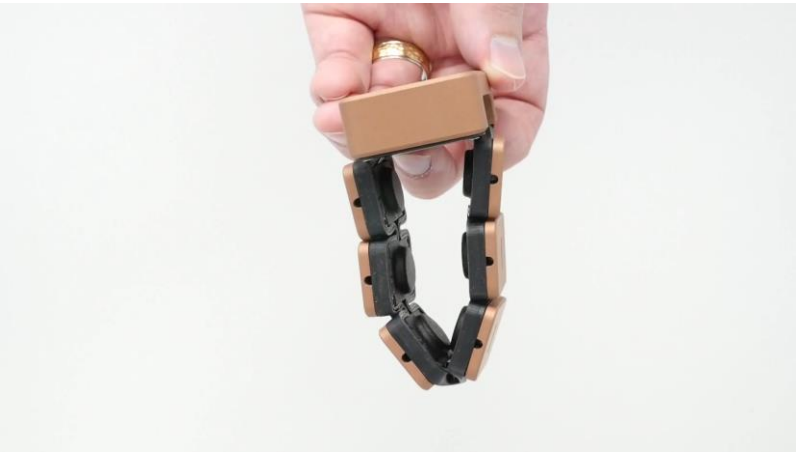


Zhakypov et al. IEEE TRO, 2018



Williams et al. in prep, 2021

Tasbi: squeeze and vibration for referred haptic feedback



Pezent et al., IEEE WHC 2019
Pezent et al., (in review)

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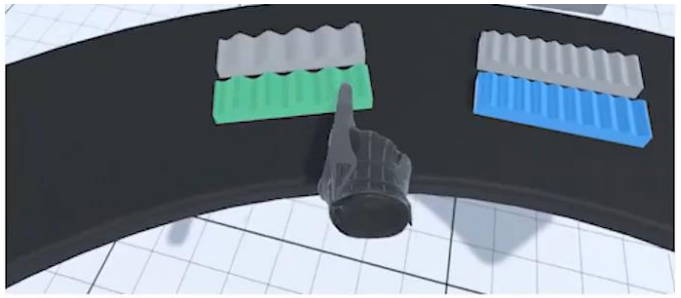
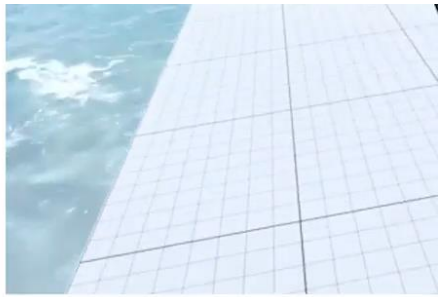
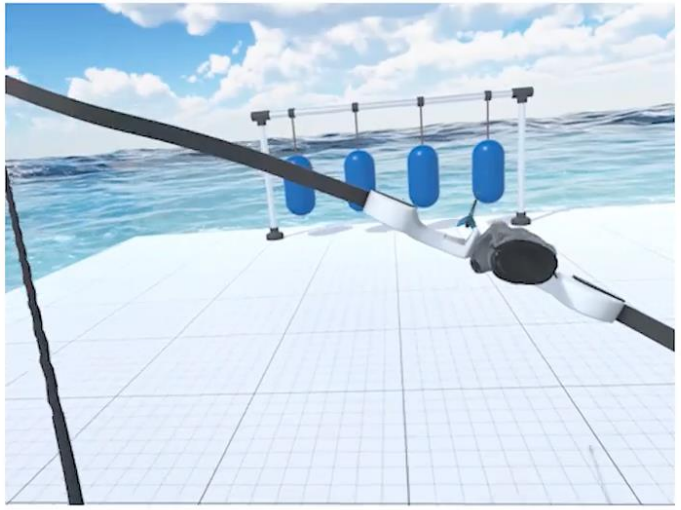
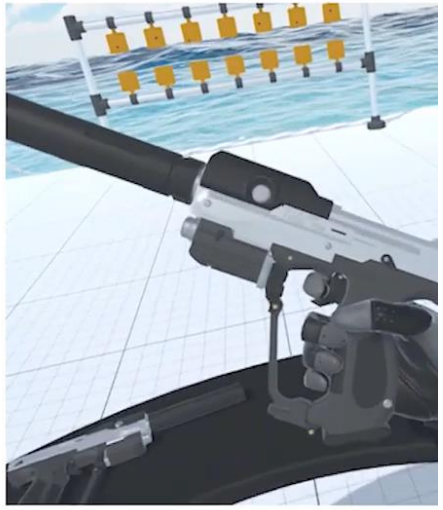
Tasbi: squeeze and vibration for referred haptic feedback

Pezent et al., CHI 2020
Pezent et al., (in review)

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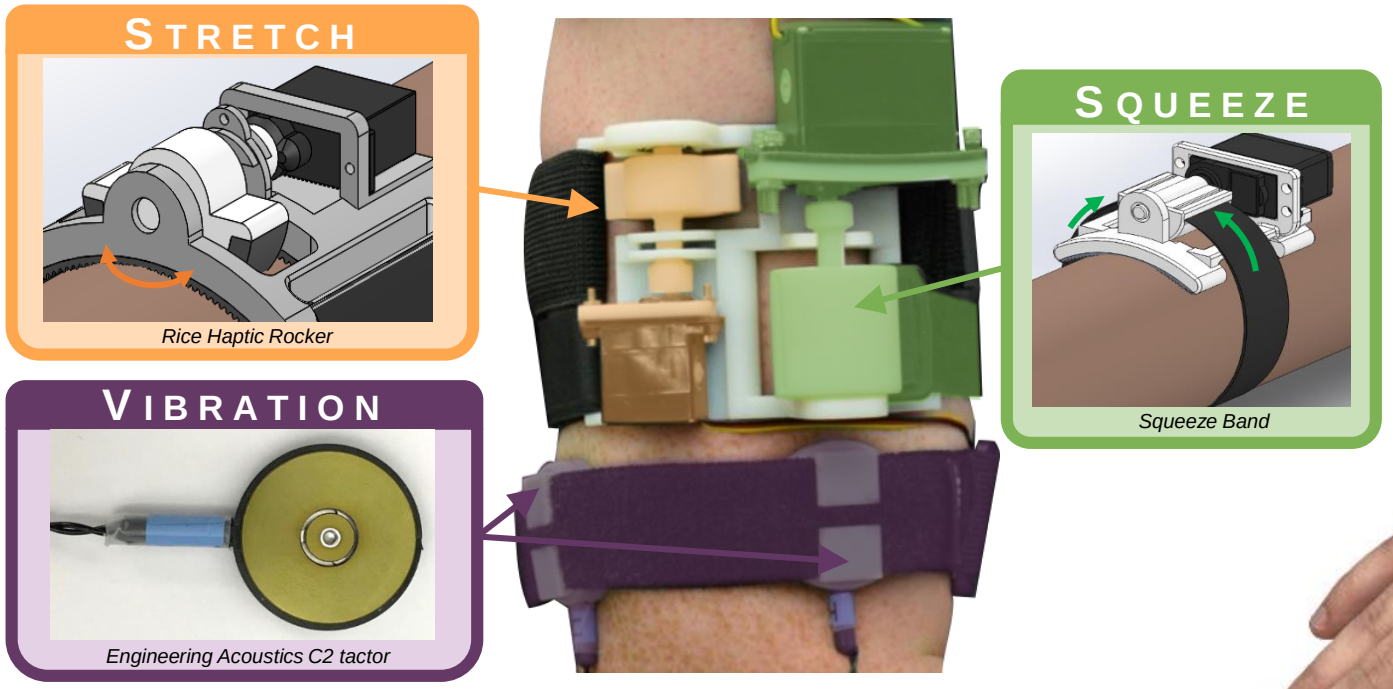
Modular wearable haptic devices

The **MAHI MISSIVE** is a compact actuator system designed to render a variety of **multi-sensory cues** on the upper arm using three haptic modes: lateral skin **stretch**, radial **squeeze**, and **vibration**



Sullivan et al., IEEE ToH 2020
Dunkelberger et al., IEEE ToH in press

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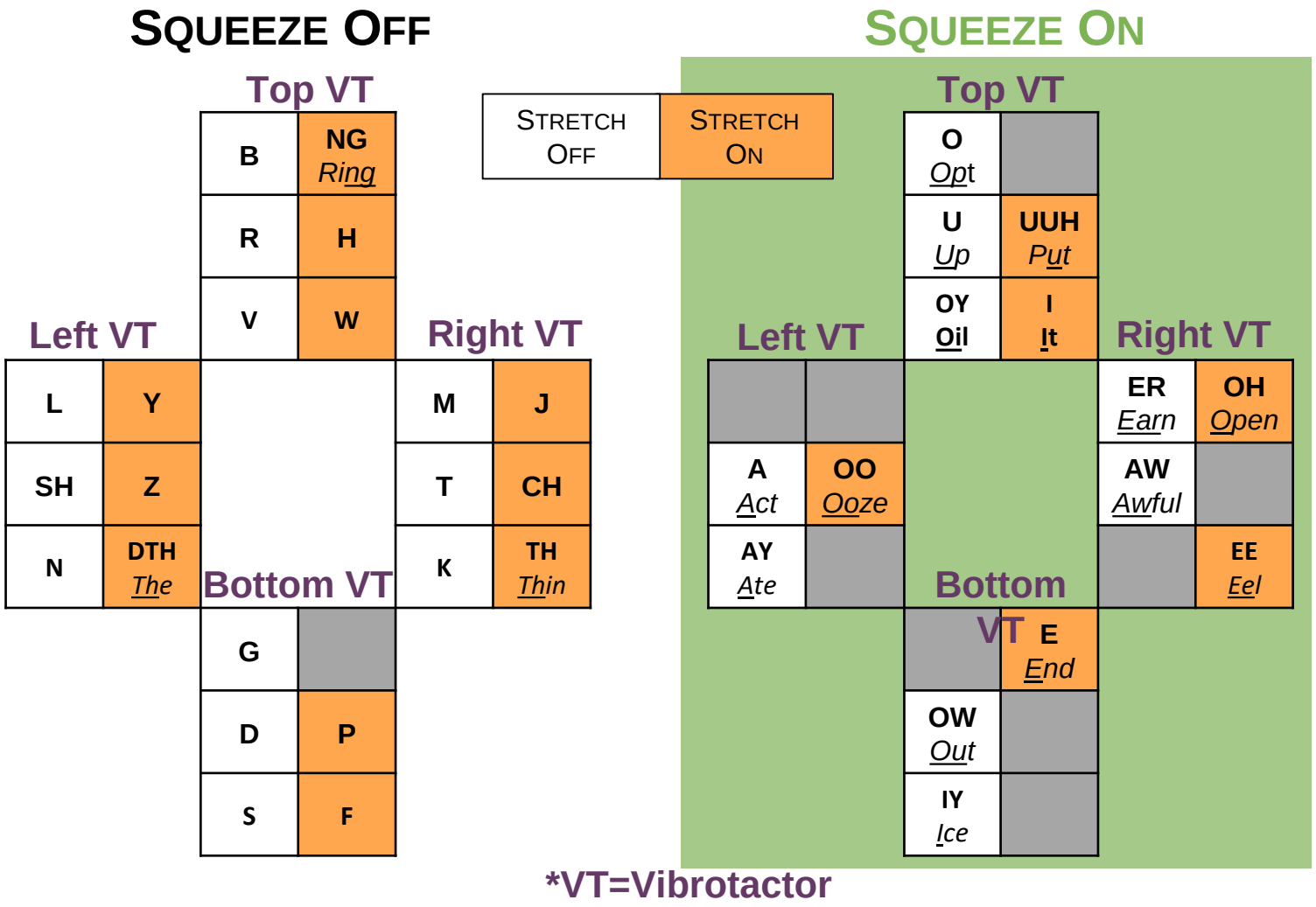
Conveying language via haptic phonemes



Dunkelberger et al., ISWC 2018, IEEE ToH 2020

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Modular wearable haptic devices

SNAPTICS

snaptics.org

- Open source, low-cost, platform for accessible prototyping of haptic devices
- Modules offer vibration, stretch, and twist cues with untethered, battery-powered operation

Zook et al., (in review)

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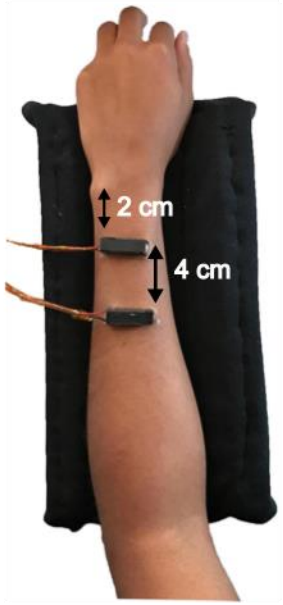
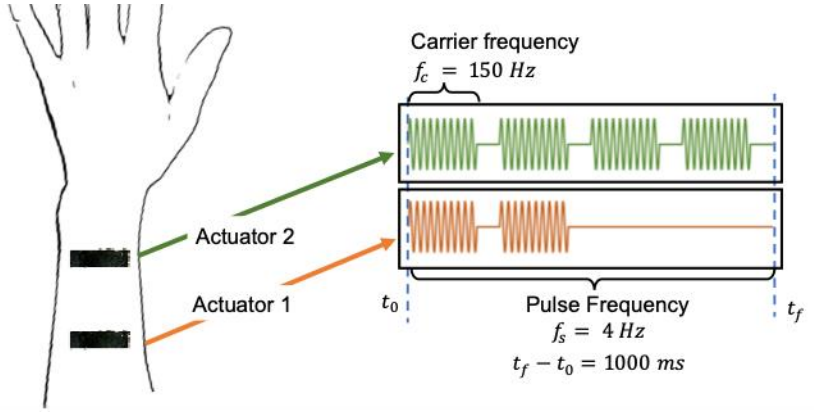
Arms vs. Fingertips, revisited

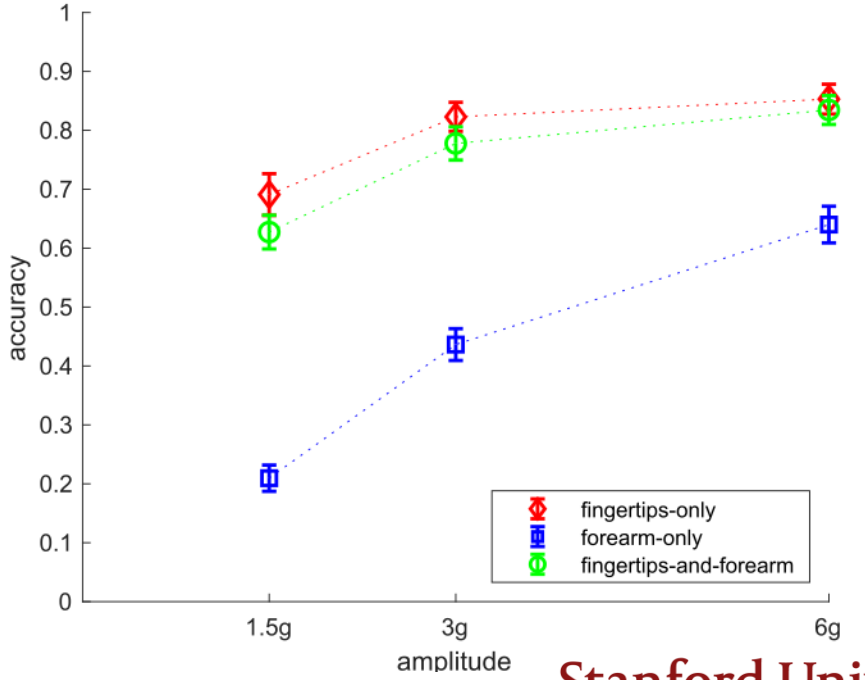
fingertips



arm

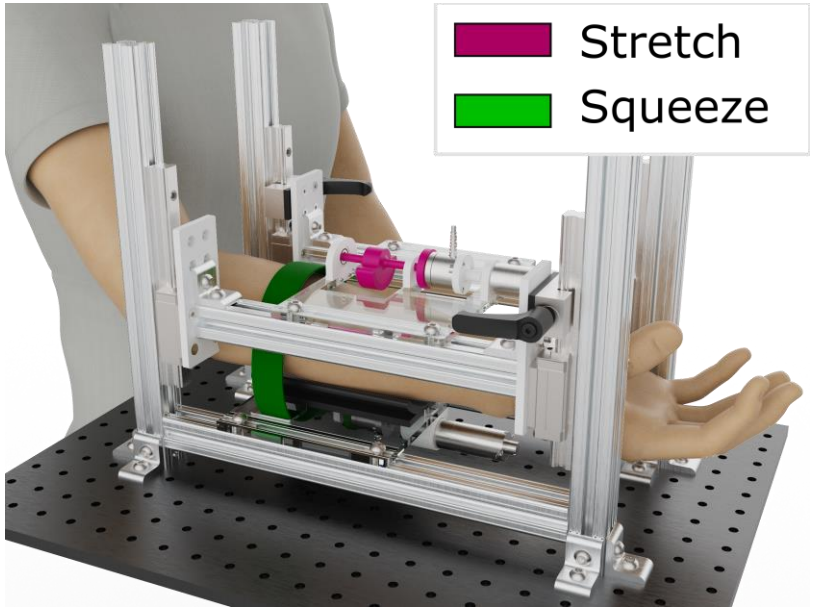
fingertips+arm

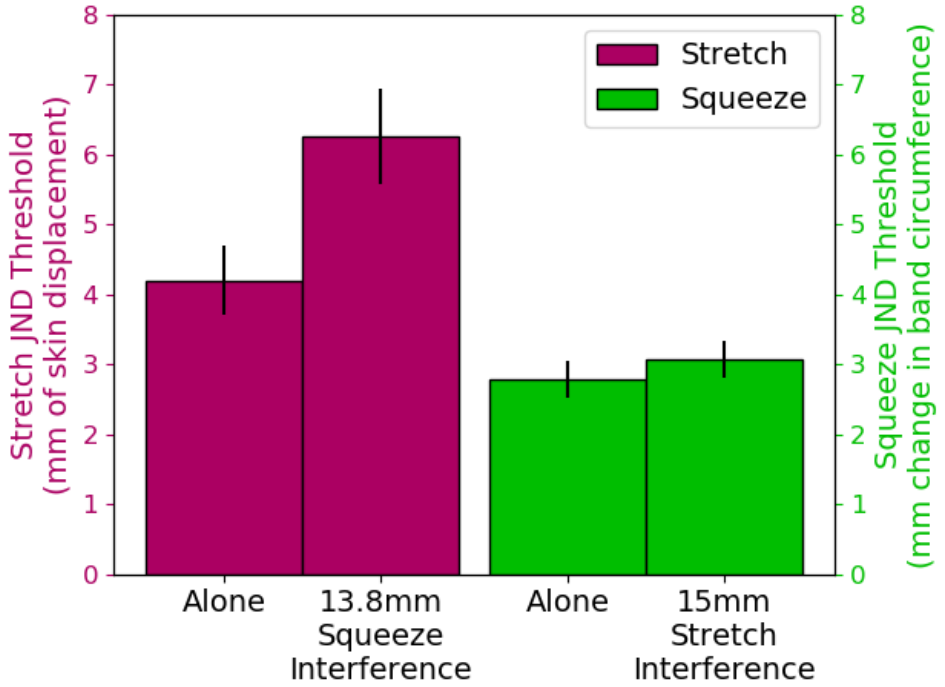


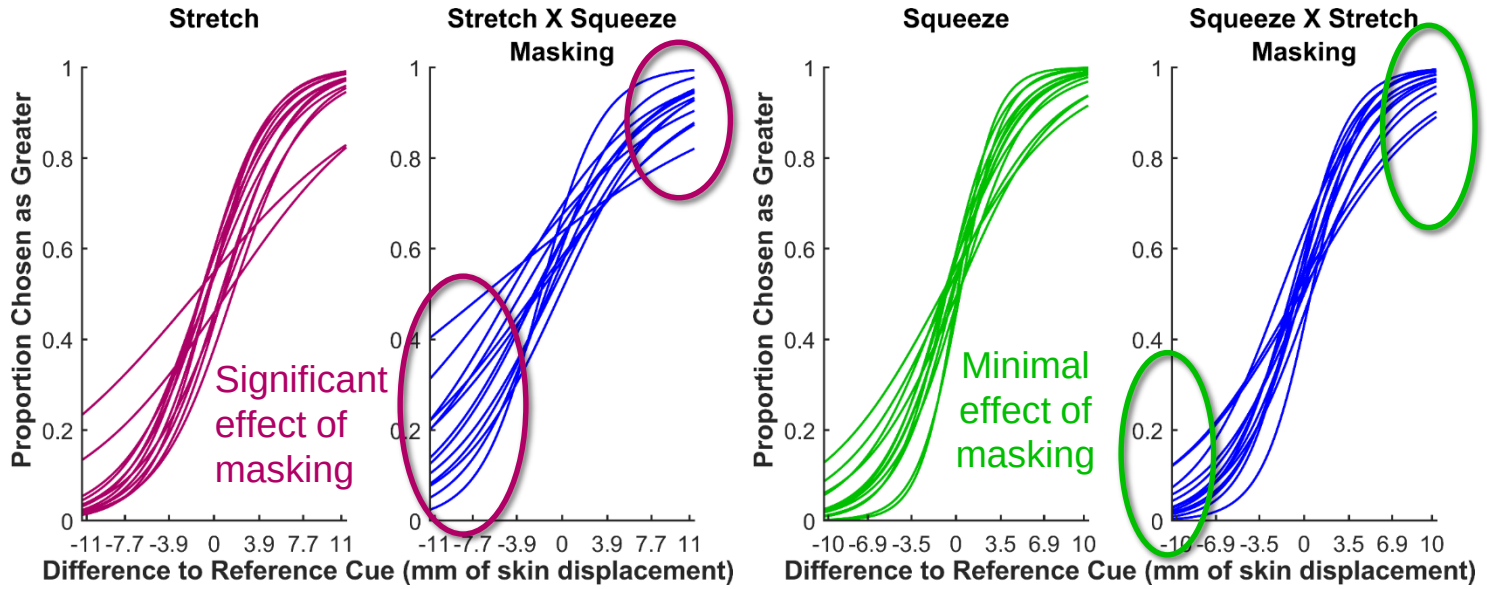


Williams and Okamura, ToH 2021

Perception of simultaneously delivered cues







Zook et al., IEEE WHC 2019
Zook et al., (in review)

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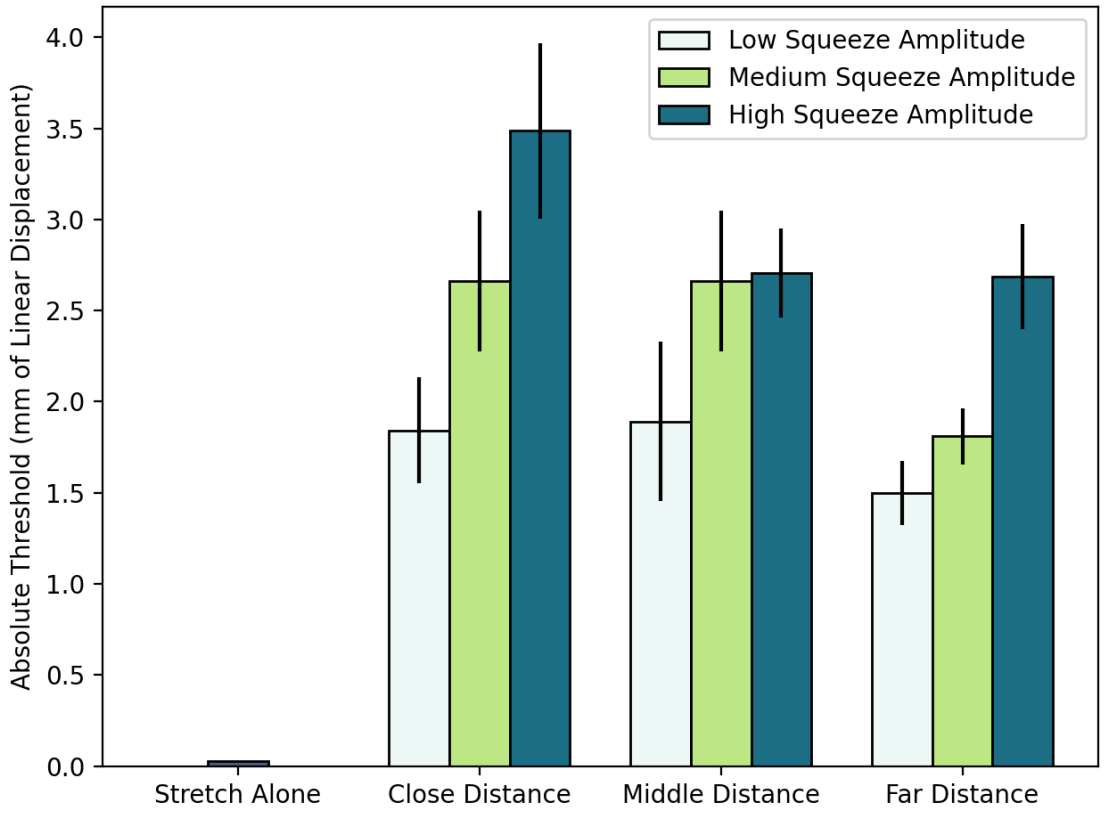
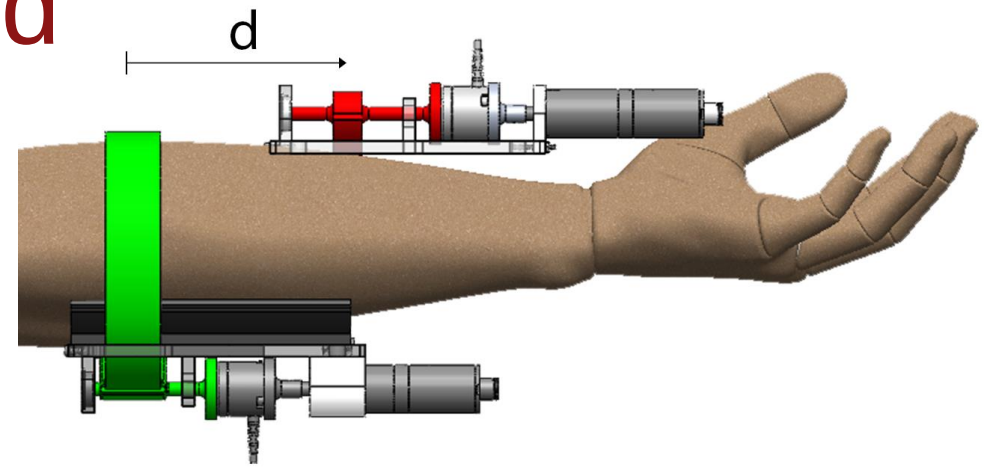
Effect of cue amplitude and separation distance



Low et al., (in review)



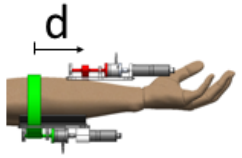
Without Interference — Stretch Detection

With Interference

Interfering Cue Amplitude

Low, Medium, High

Inter-cue Distance



Close, Middle, Far

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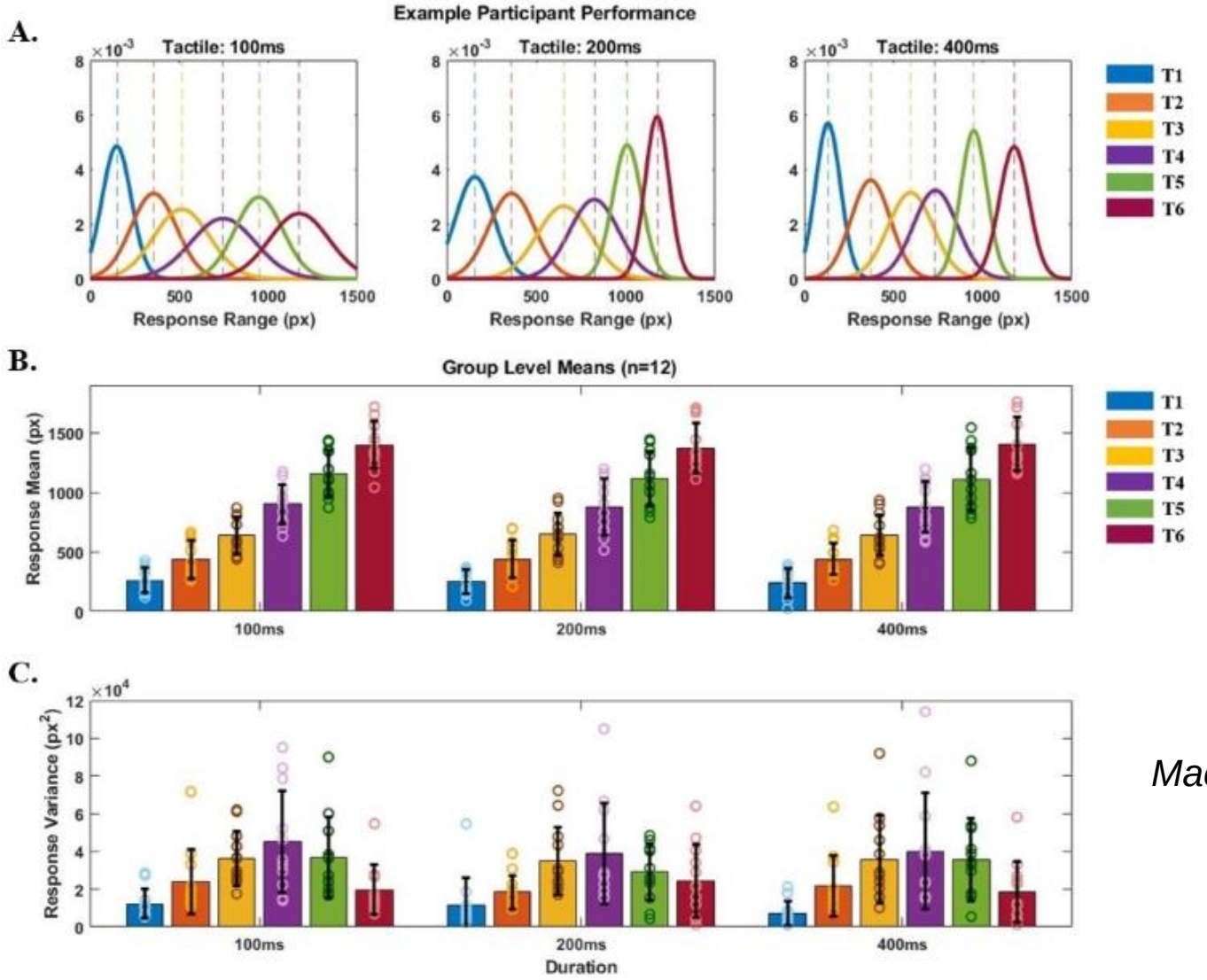
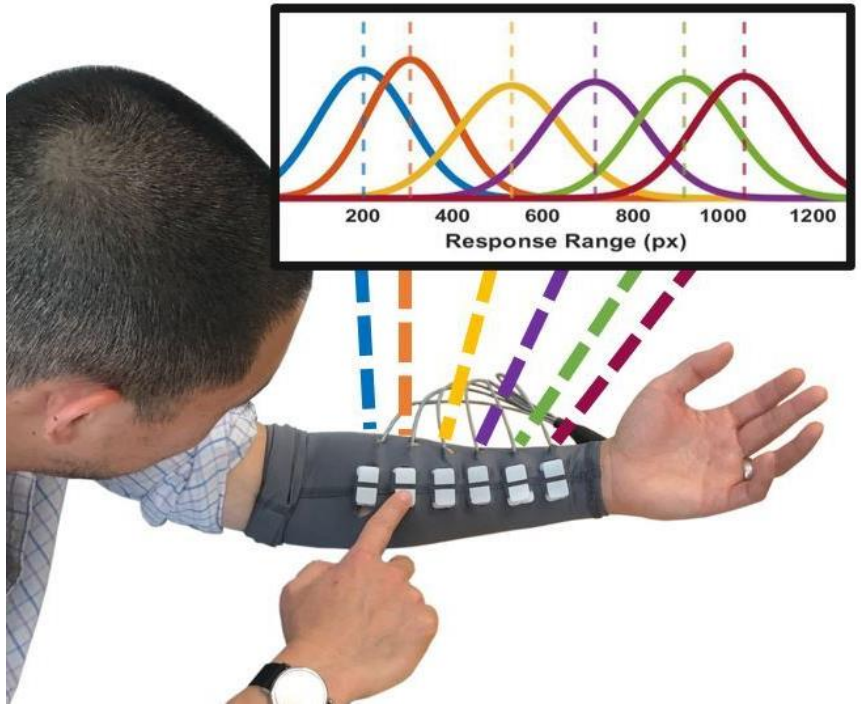
Vibrotactile cue localization for associative learning





Macklin et al., (in review)

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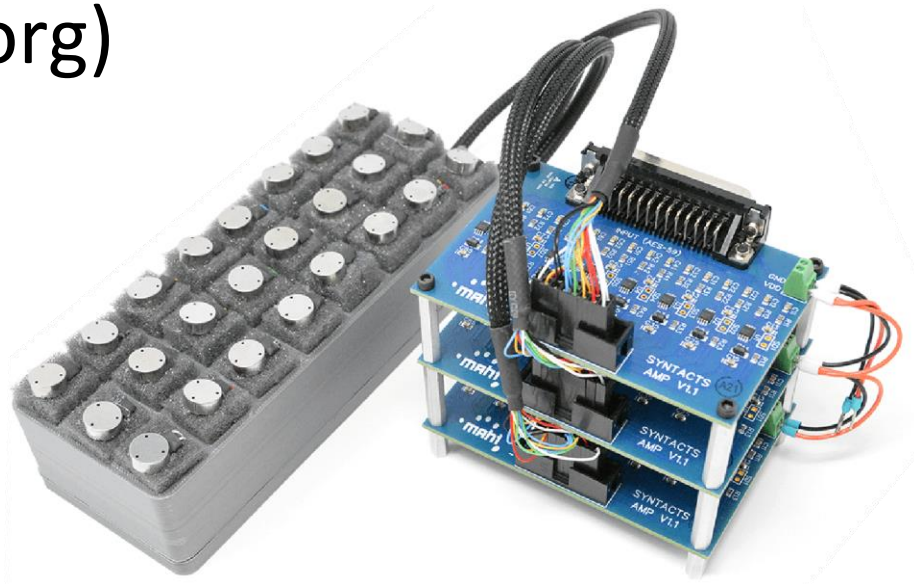
Open-source tools for wearable haptics

syntacts

Open-sourced software and hardware framework to simplify vibrotactile haptics. Debuted at IROS 2020 tutorial (see syntacts.org)



Pezent et al., IEEE ToH (in press)

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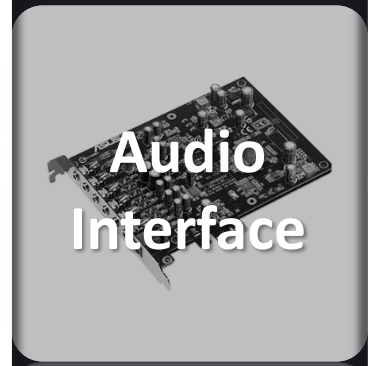
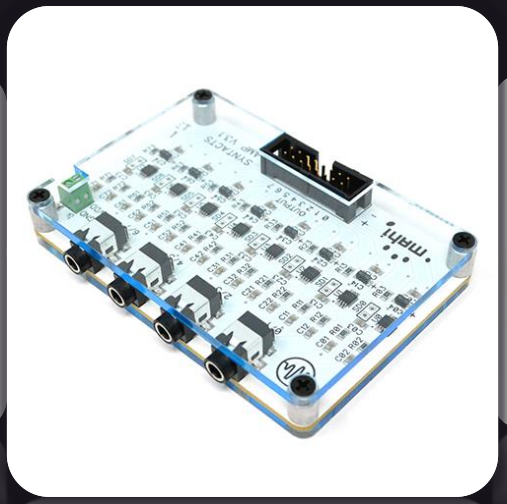
audio driven haptics with syntacts

Software



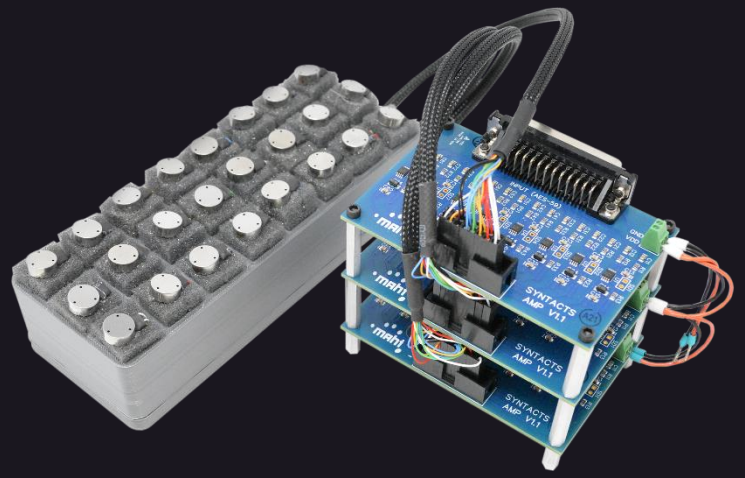


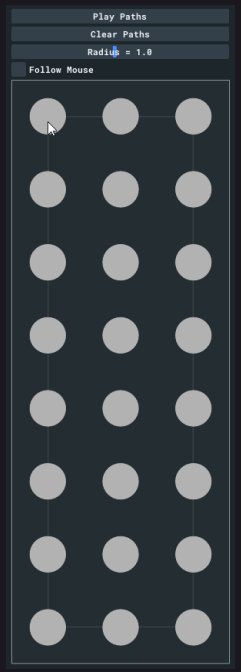
Power
Amp

example projects

syntacts array

syntacts.org/tutorials/draw





syntacts bracelet

syntacts.org/tutorials/bracelet

syntacts

mAhi

- contact: info@syntacts.org
- tutorials: syntacts.org/tutorials
- software: github.com/mahilab/Syntacts
- amplifiers: syntacts.org/hardware
- devices: syntacts.org/hardware

evan pezent

brandon cambio

lianne johnson

roderico garcia

ahalya lettenberger

marcia o'malley

Plans for our final year

- Integrate improved actuation techniques into our soft haptic device designs
- Characterize whole-body and multi-modal haptic perception and translate results to improved device design
- Explore applications in affective haptics, prosthetics, and haptic communication
- Disseminate our low-cost, open-source wearable haptic hardware and software tools (syntacts and snaptics)