

# EMS course

hands-on course on electrical muscle stimulation

pedro lopes, max pfeifer, michael rohs, patrick baudisch @ CHI'16

in this course you will be able to create interfaces  
that talk directly to the human body



interfaces that talk directly to the user's body  
and are based on the proprioceptive sense

interfaces that talk directly to the user's body  
and are based on the proprioceptive sense

we'll be guiding you through the basics of  
how to actuate muscles using EMS (electrical  
muscle stimulation)

interfaces that talk directly to the user's body  
and are based on the proprioceptive sense

**we'll be guiding you through the basics of  
how to electrically actuate muscles using EMS**



<http://theundreamhosters.com/future>  
pedro lopes



max pfeiffer



tim dünte



michael rohs



patrick baudisch

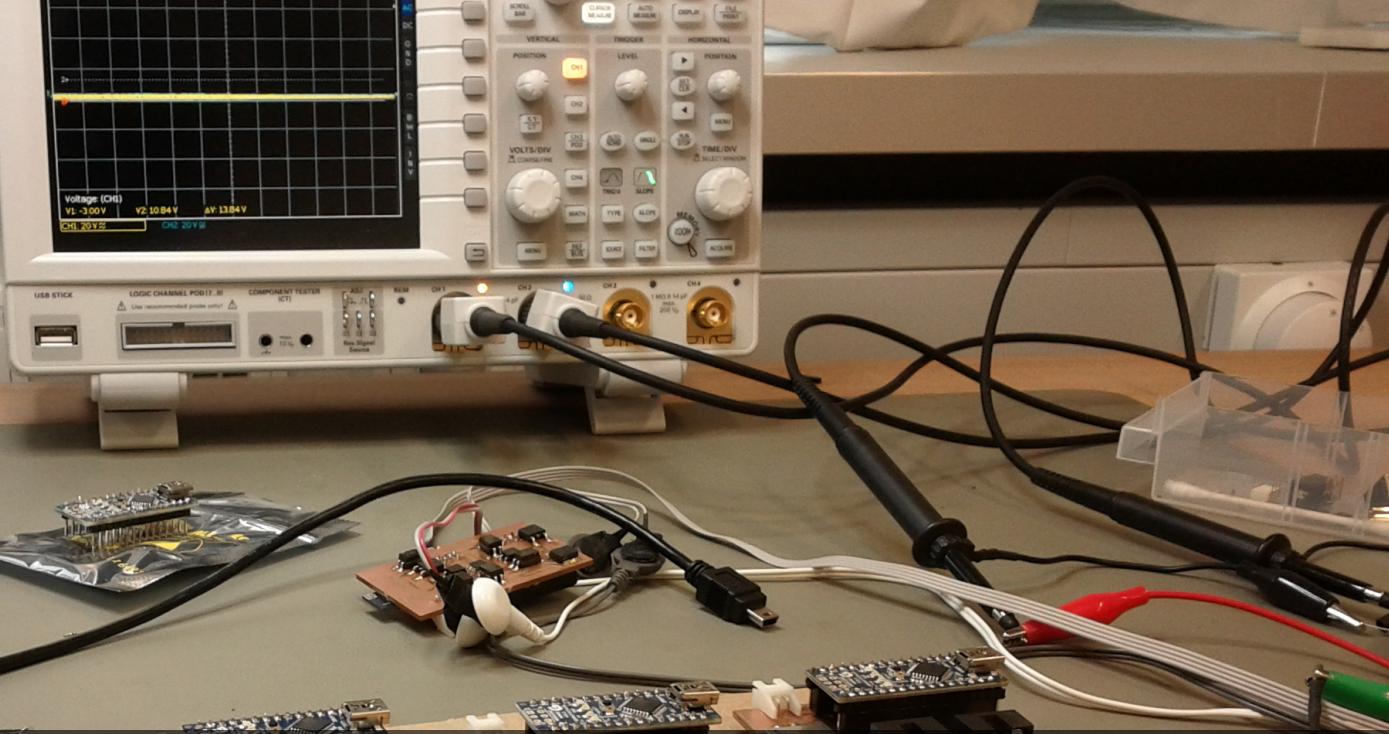
so what hardware are we using for EMS?



you'll get a EMS control kit similar to this  
... designed by Max and Tim for you!



the board is now released as open source,  
as just like we did, you can fab your own



what the board does:  
controls the amplitude of your haptic output,  
i.e., how much the user's muscles contract

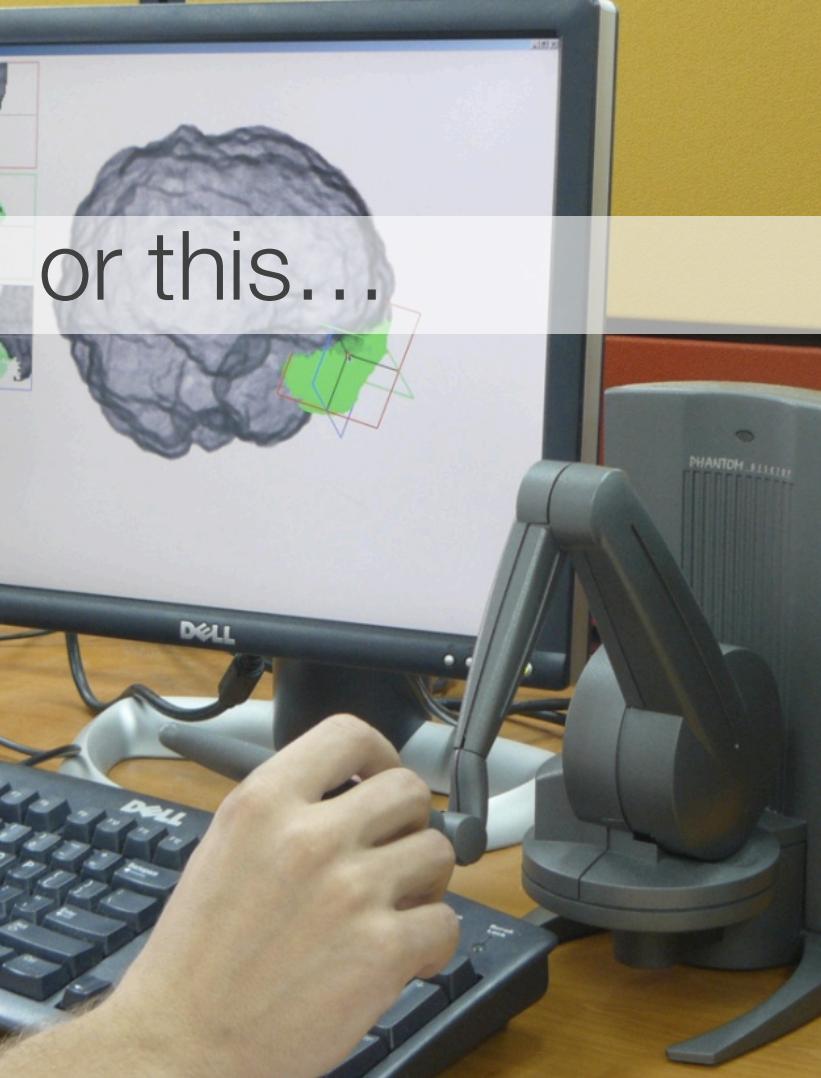


wait...  
interactive systems based on  
electrical muscle stimulation?

PhD Thesis “Proprioceptive Interaction:  
interactive systems based on electrical muscle  
stimulation” by Pedro Lopes

when you think of haptic interfaces capable  
of force output... you think of this

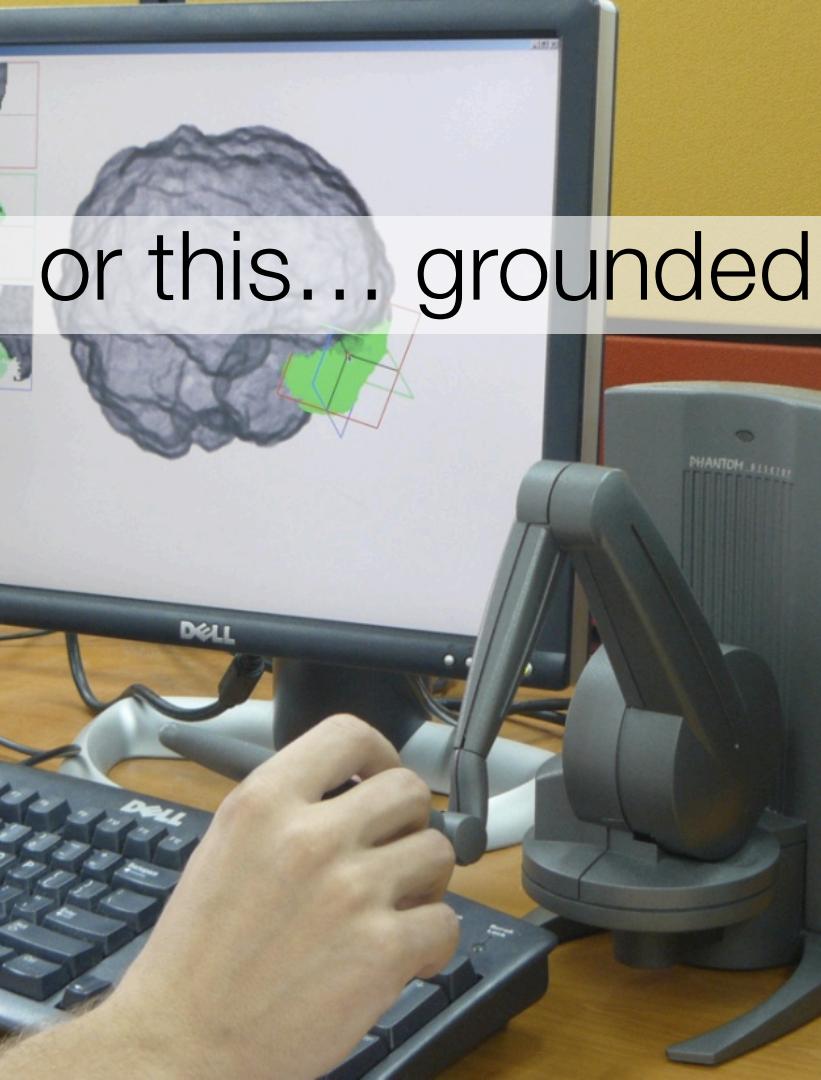




or this...

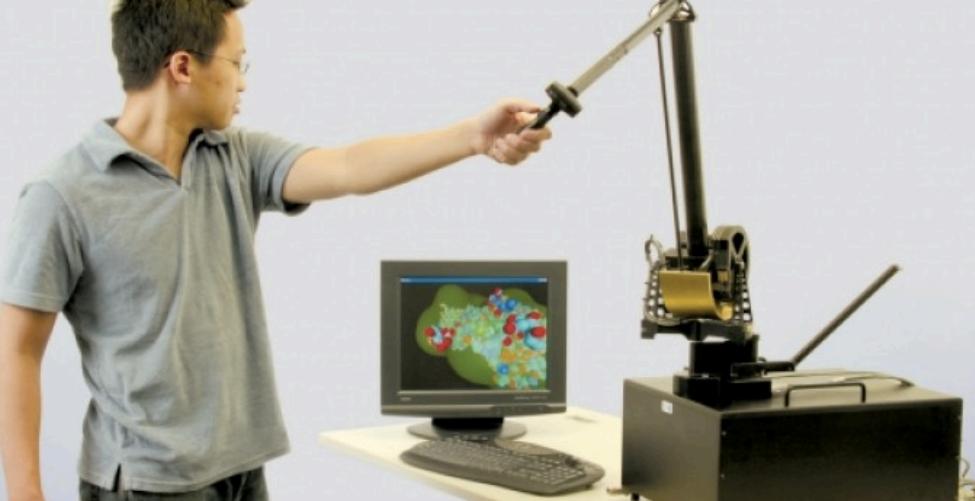


or this... grounded force feedback devices





these are great, precise and powerful



however, they don't miniaturize

and today's trend is mobility

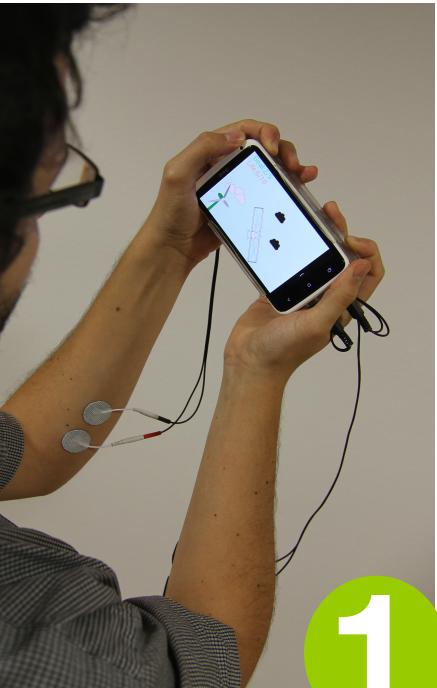


for large actuation and mobility  
researchers focused on exoskeletons  
but these are heavy and get in the way

instead...

**we design interactive systems with strong haptic forces such as force feedback**

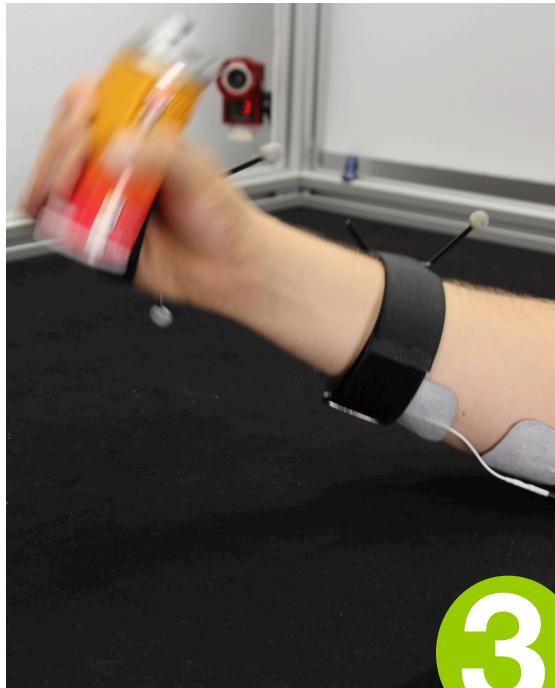
**... with a substantially smaller footprint**



1



2

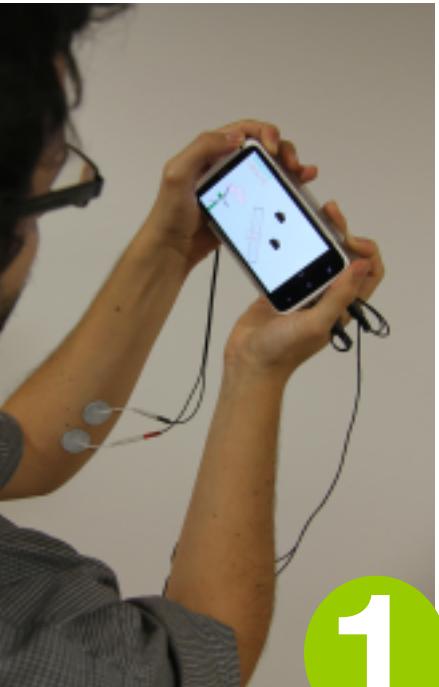


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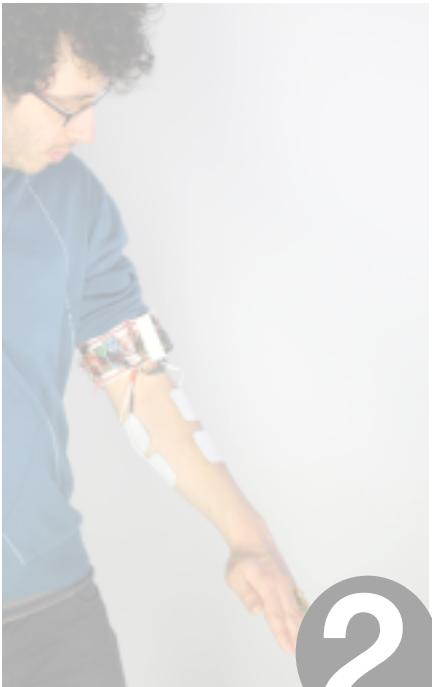


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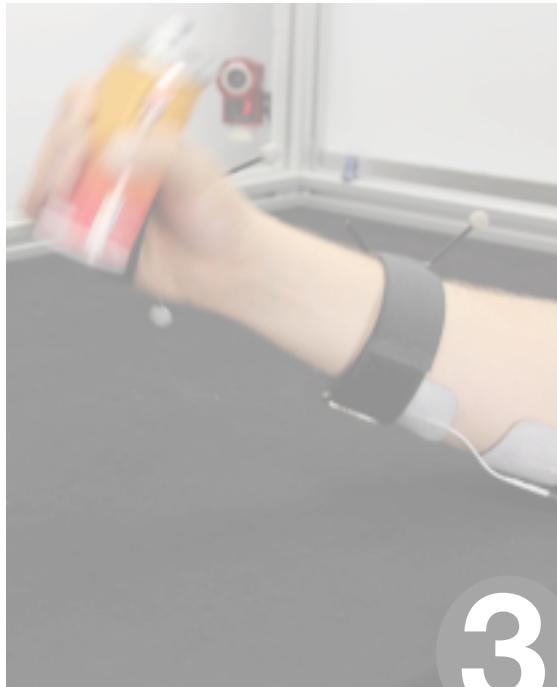
proprioceptive interfaces that r/w to the body



1



2



3



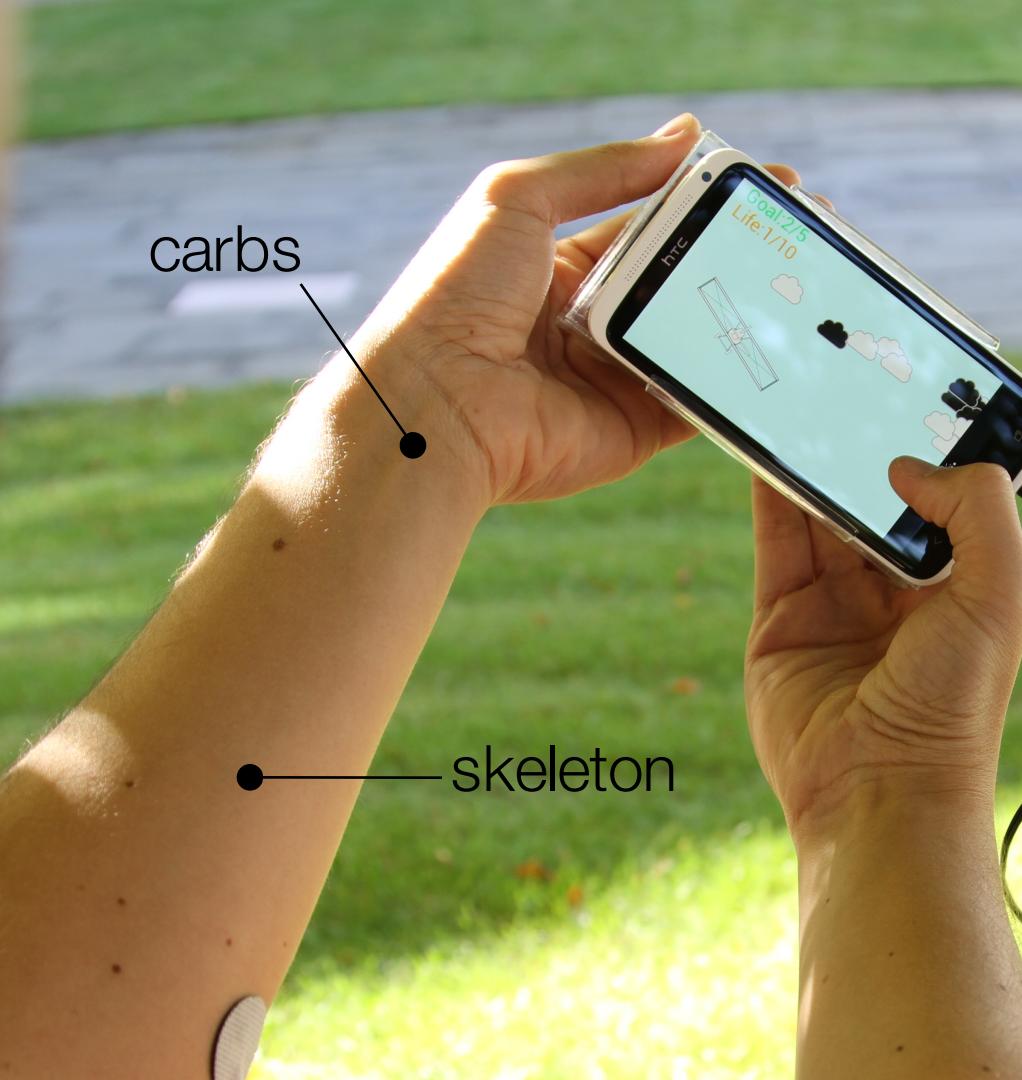
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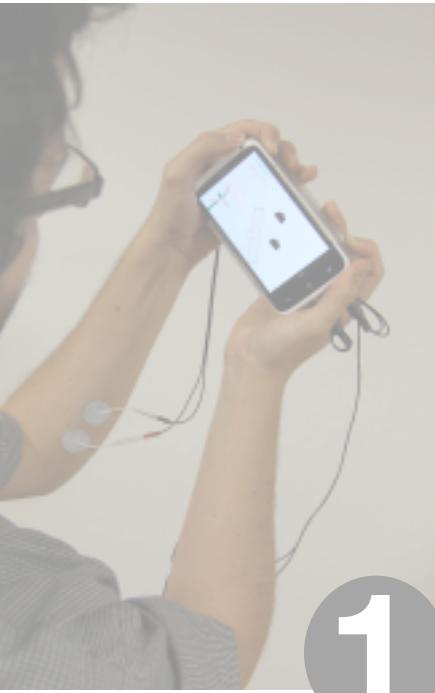
proprioceptive interfaces that r/w to the body

muscle propelled force feedback, CHI'13



... device has no motors or actuators

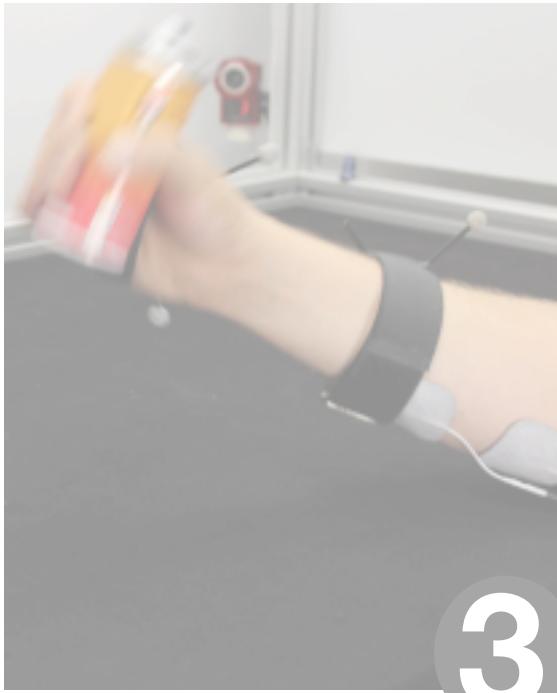




1



2



3



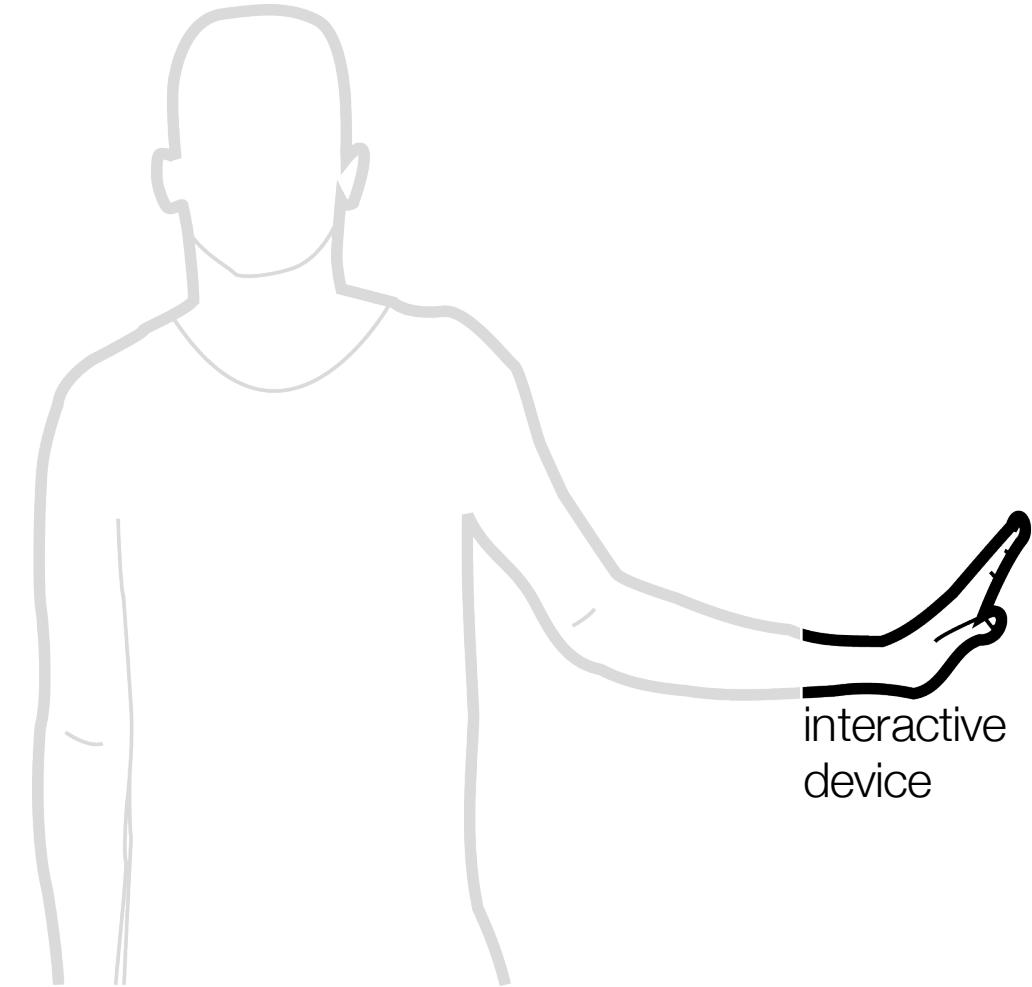
4

proprioceptive interfaces that r/w to the body

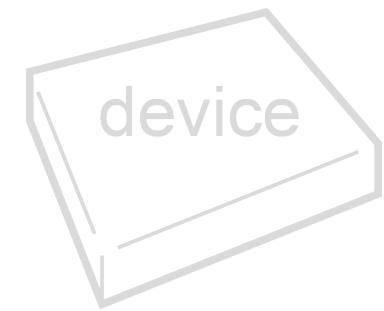
proprioceptive interaction, CHI'15

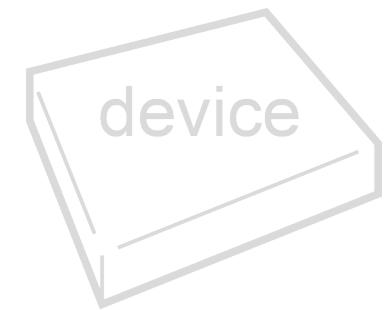
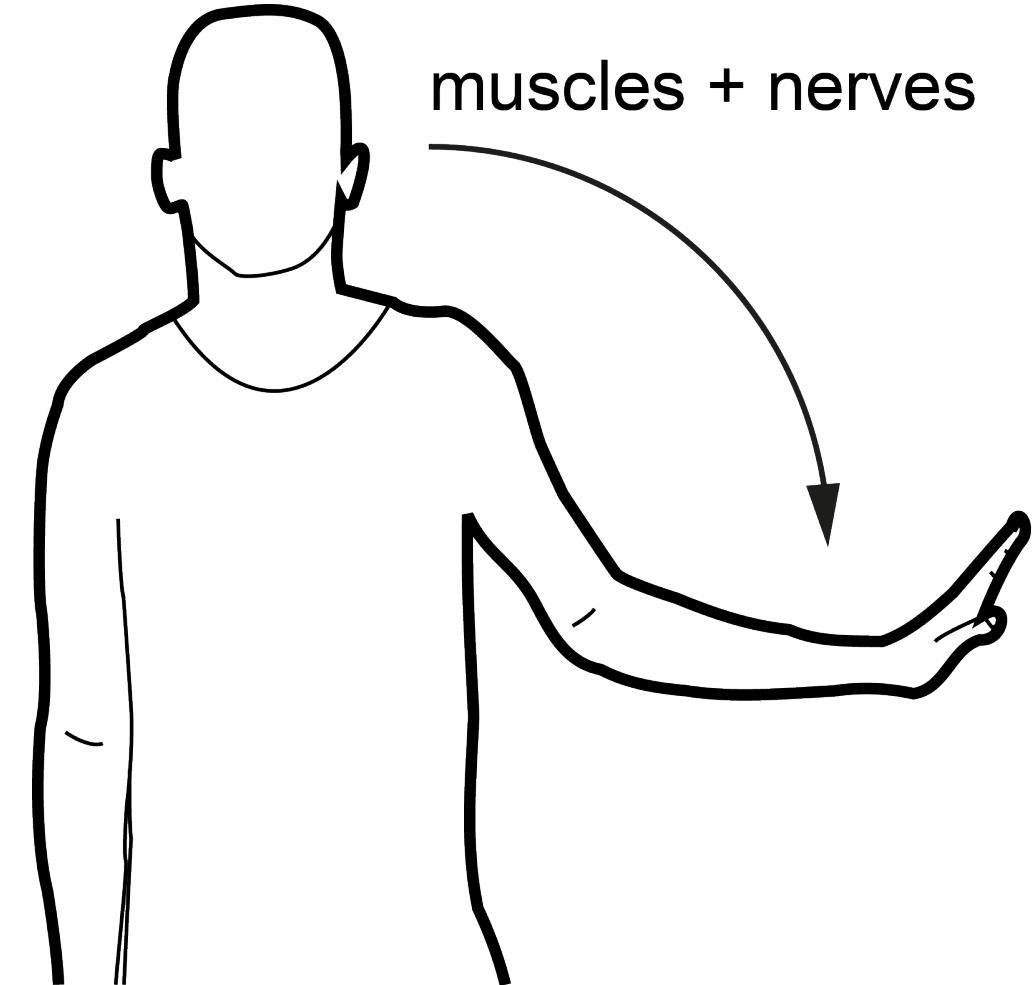
# proprioceptive interaction

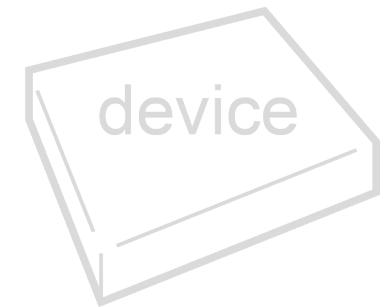
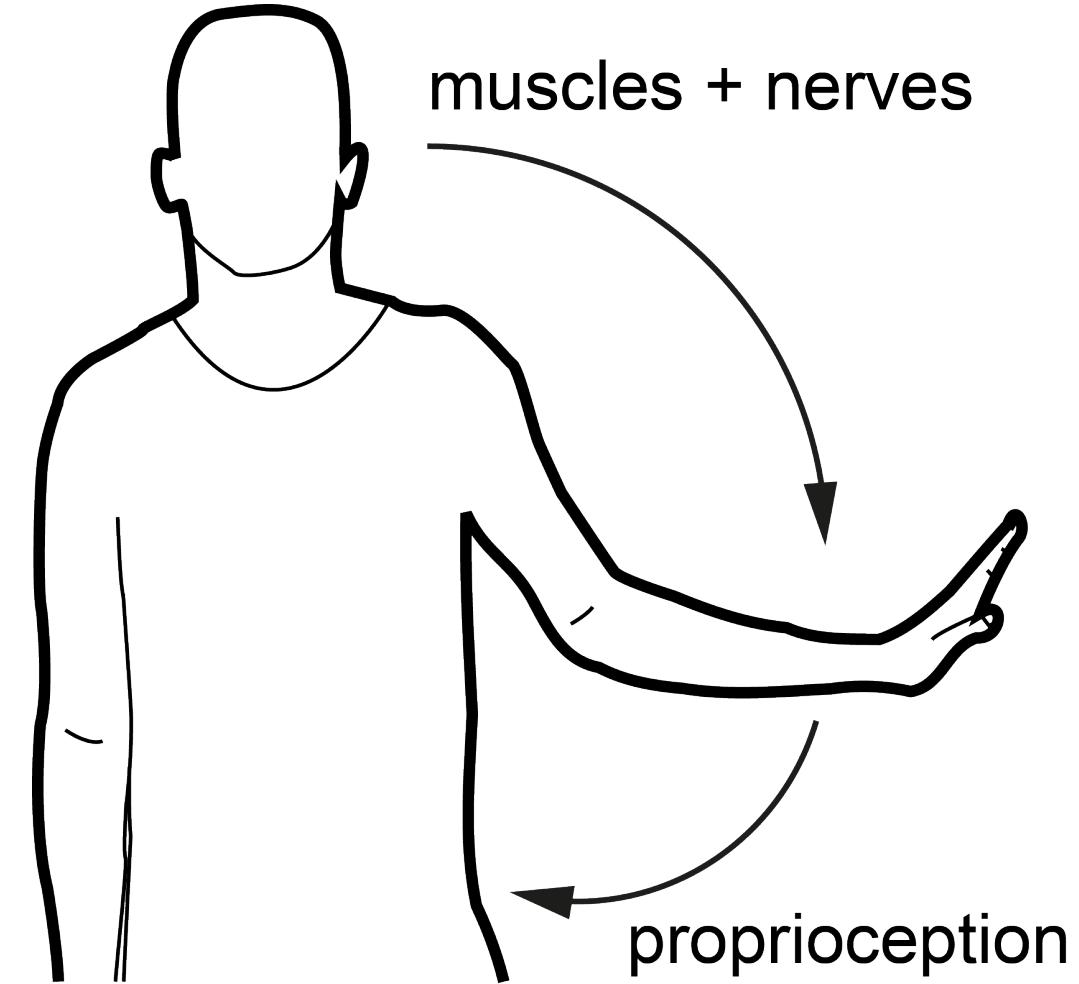
is interacting through the pose of their own body (*proprius*).  
i.e., rather than seeing, hearing, or feeling an outside stimulus,  
users feel the pose of their body.

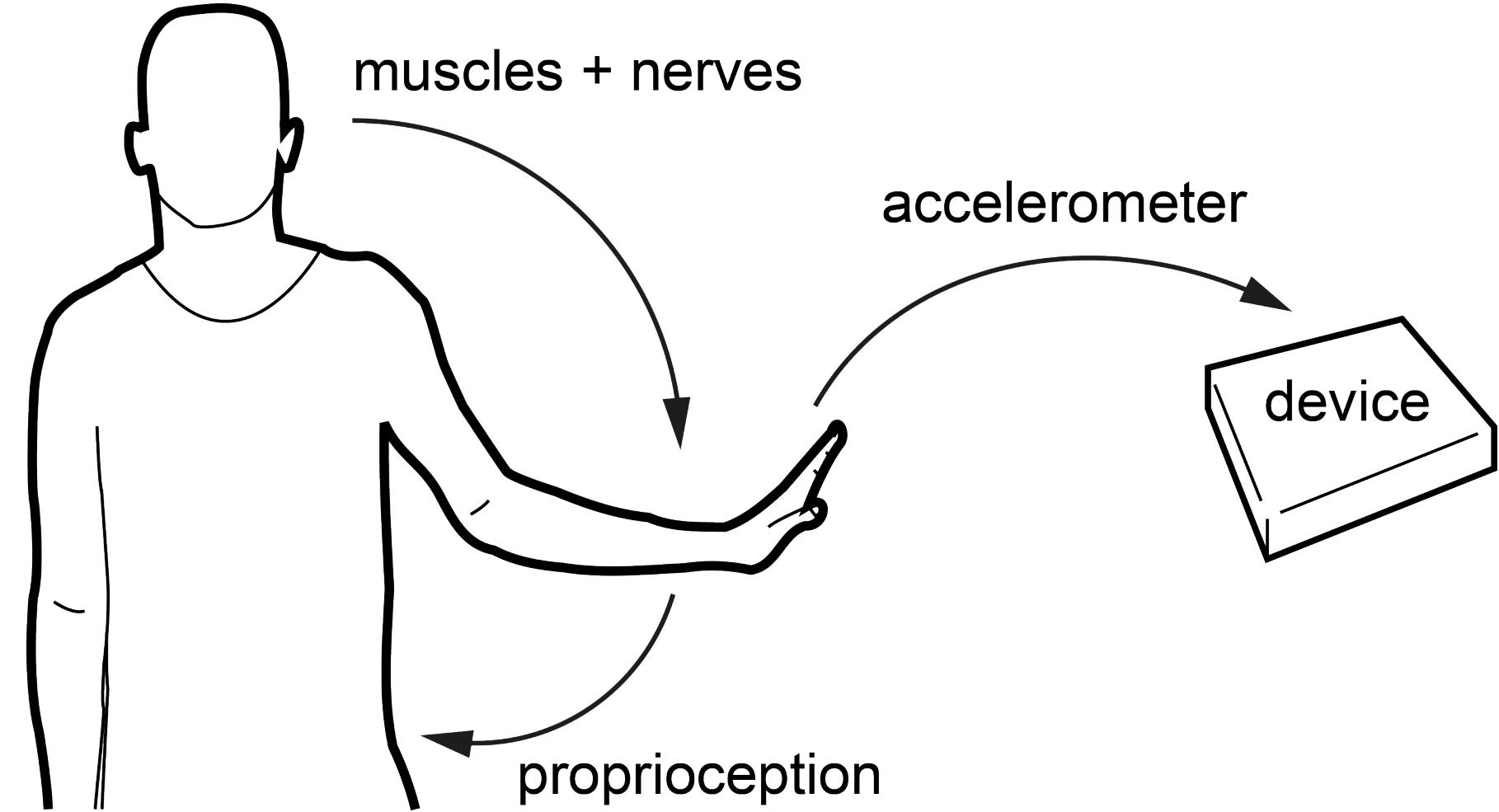


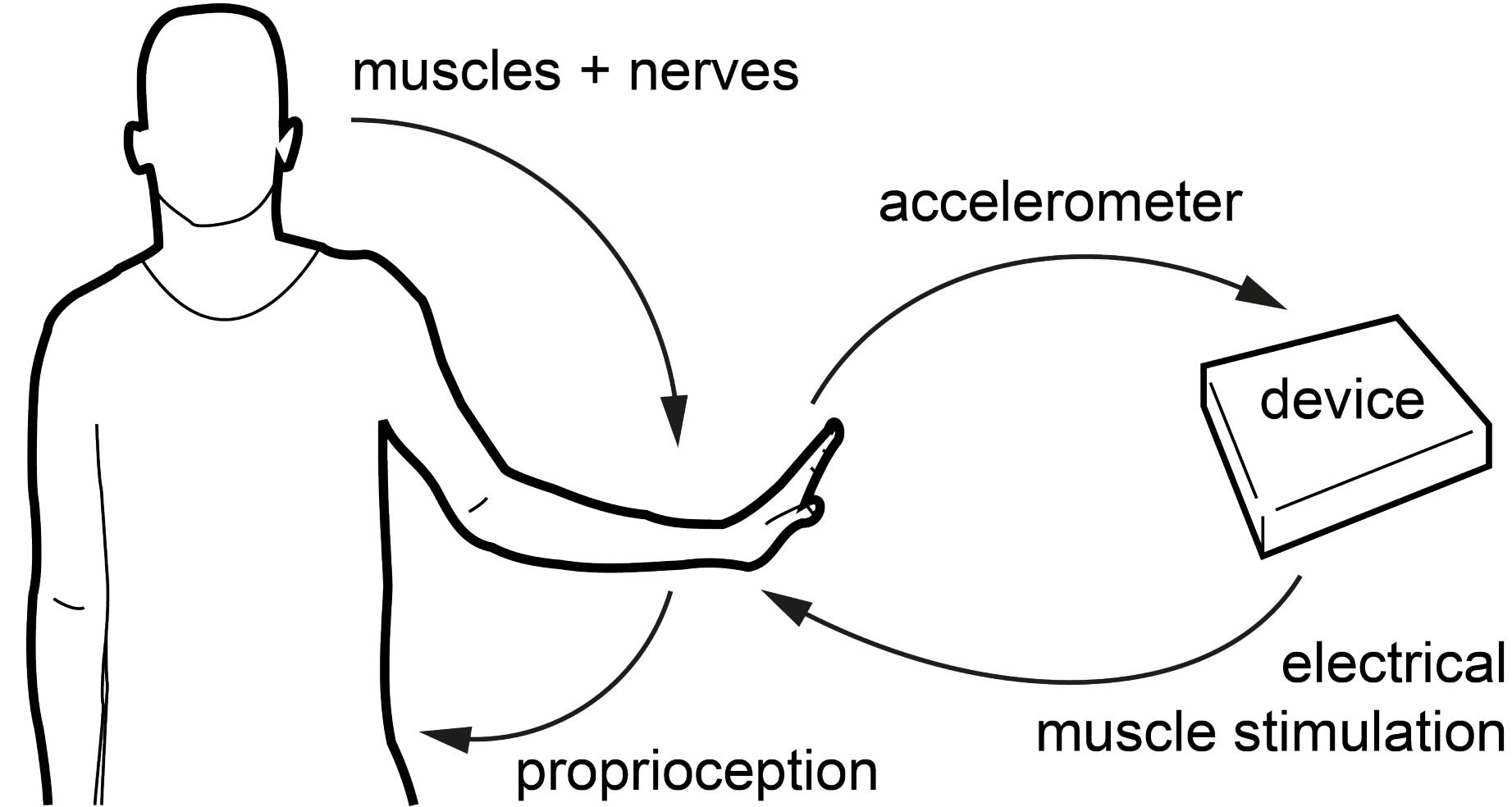
interactive  
device

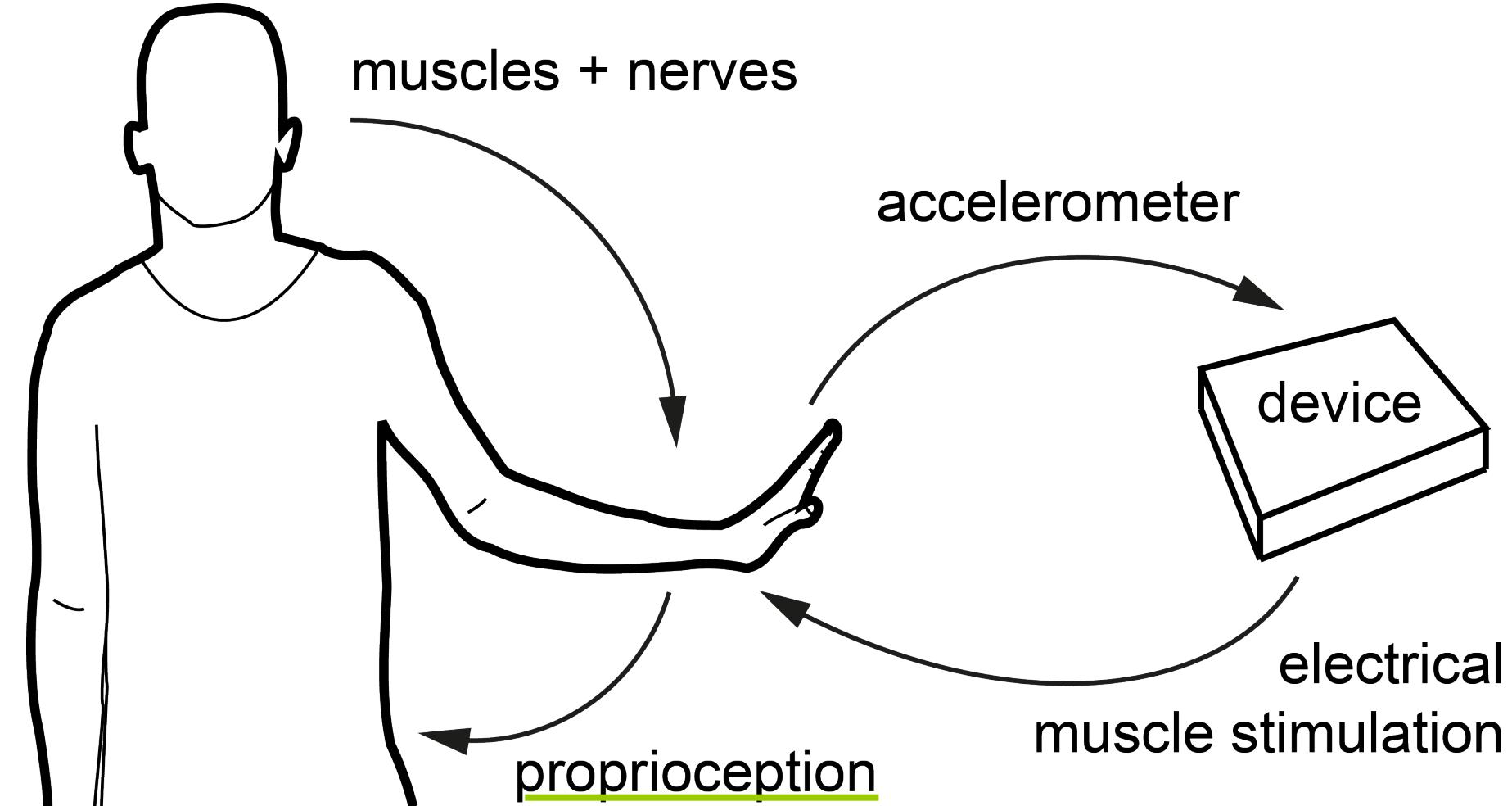


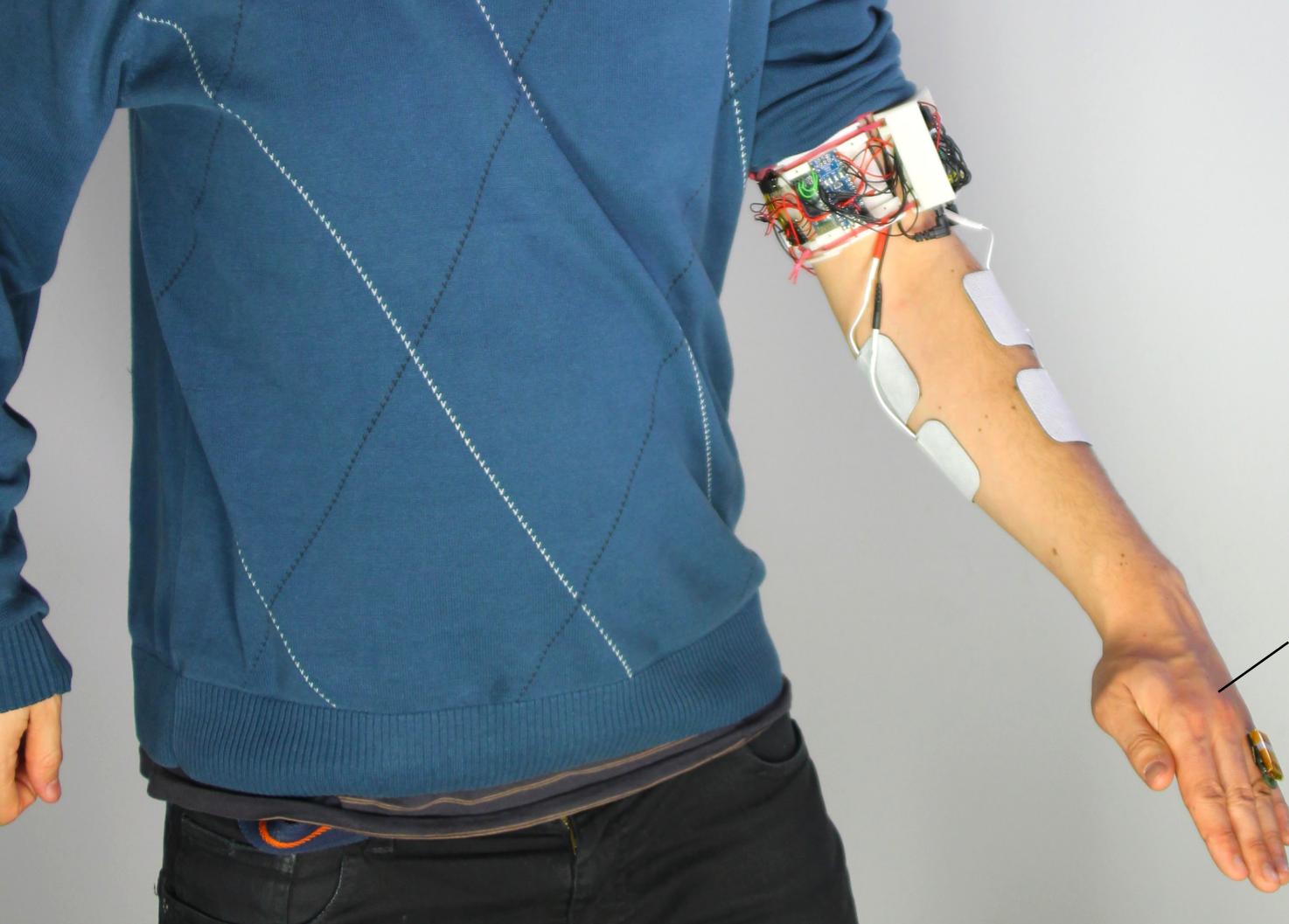




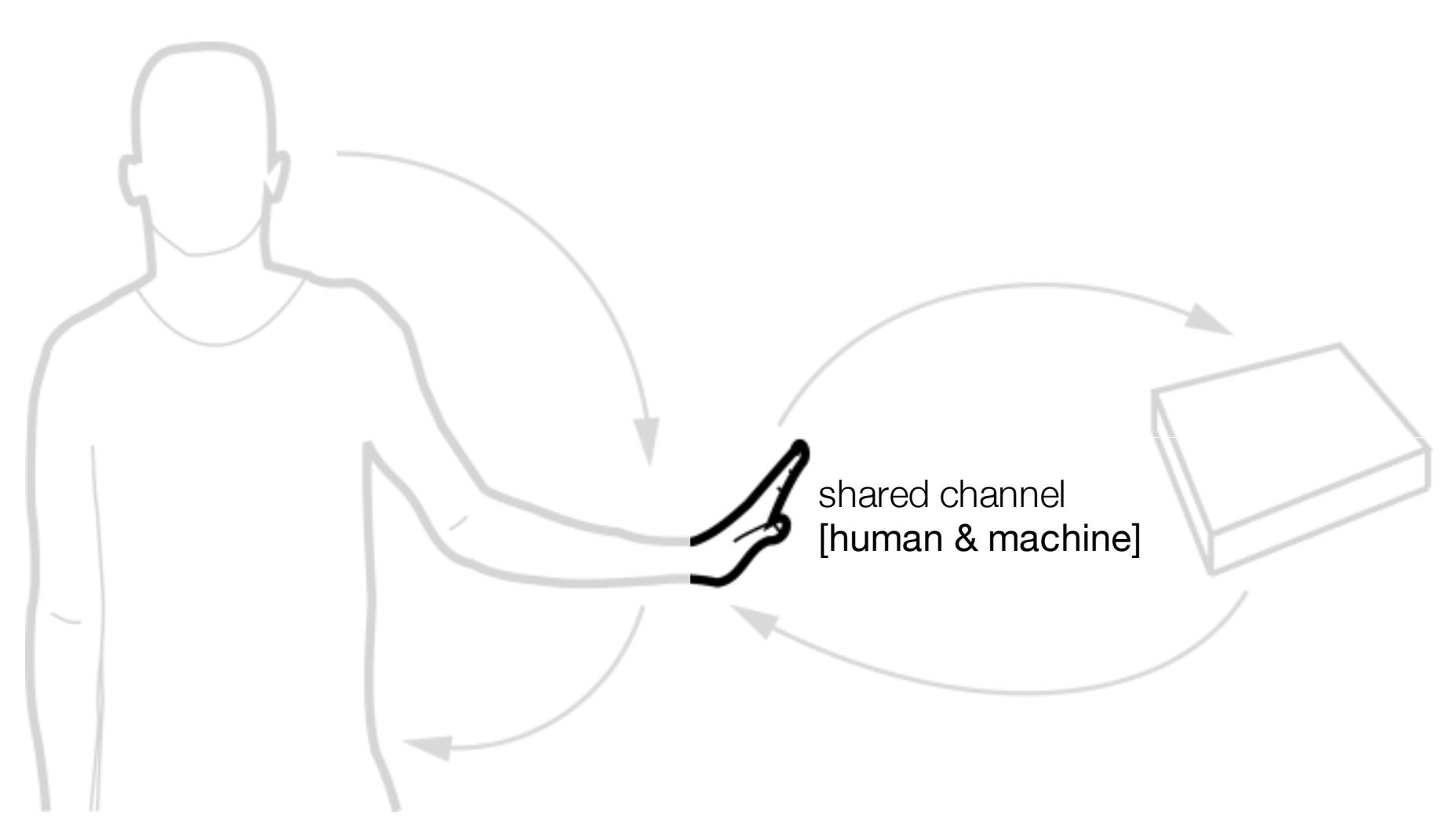


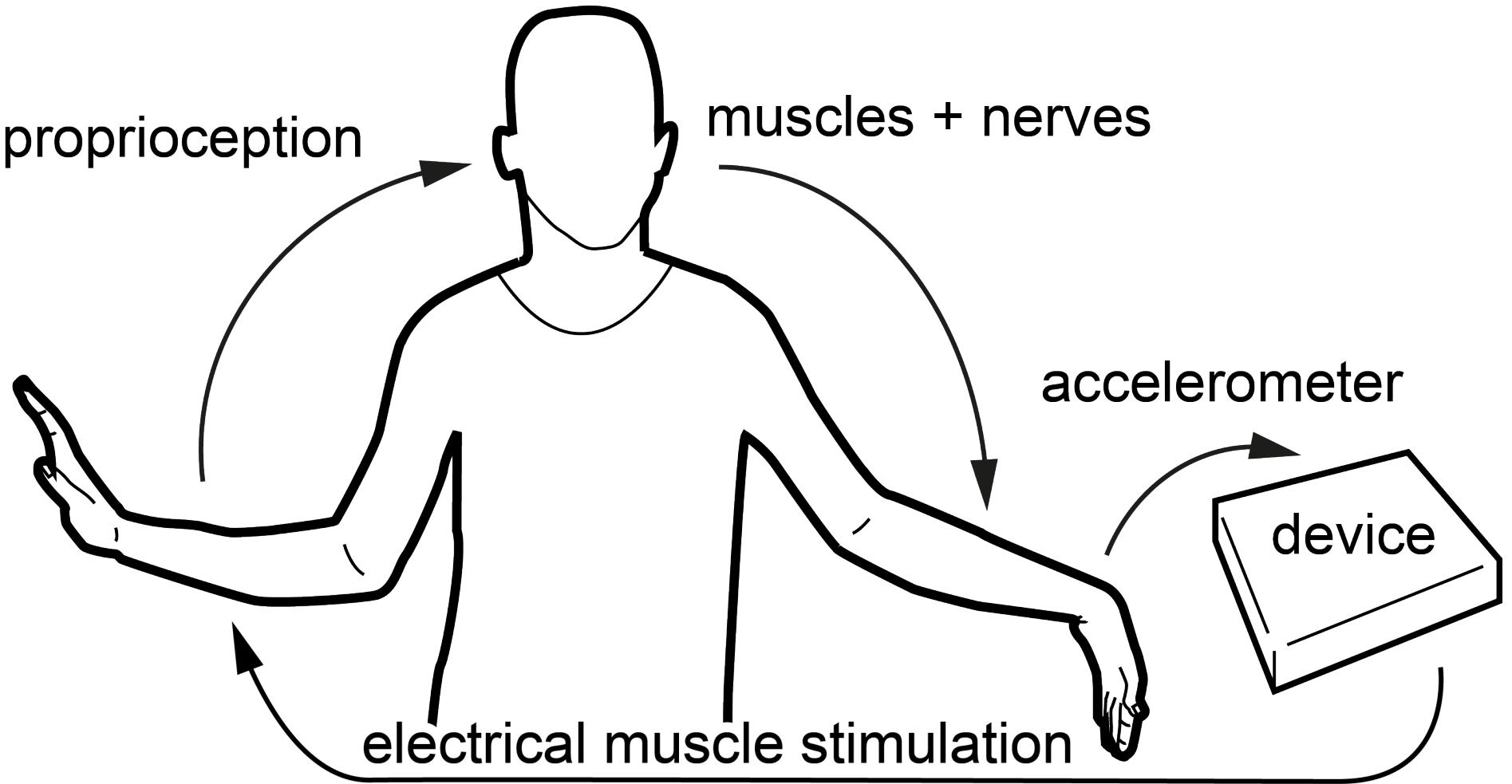


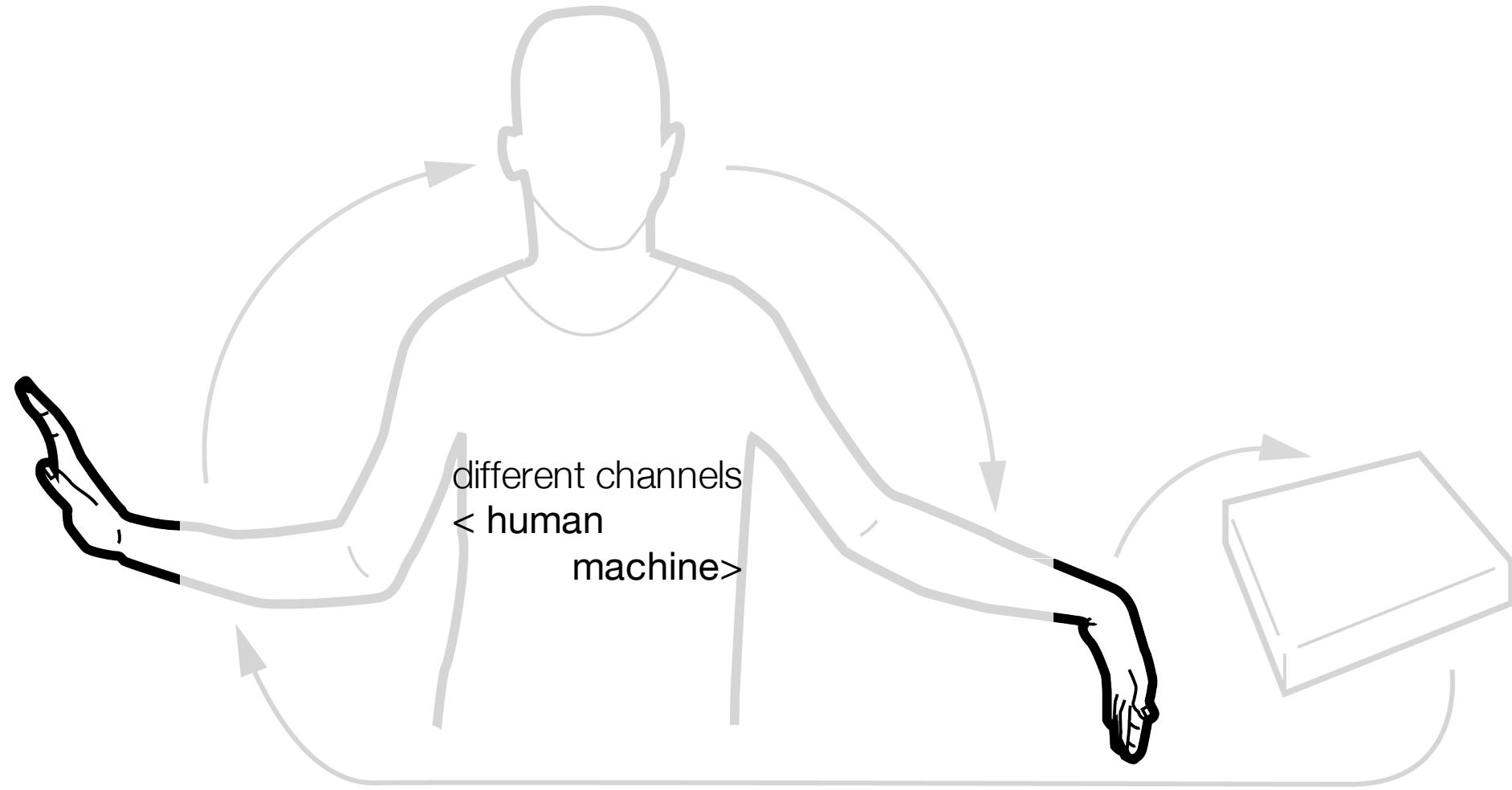




very small  
I/O device...

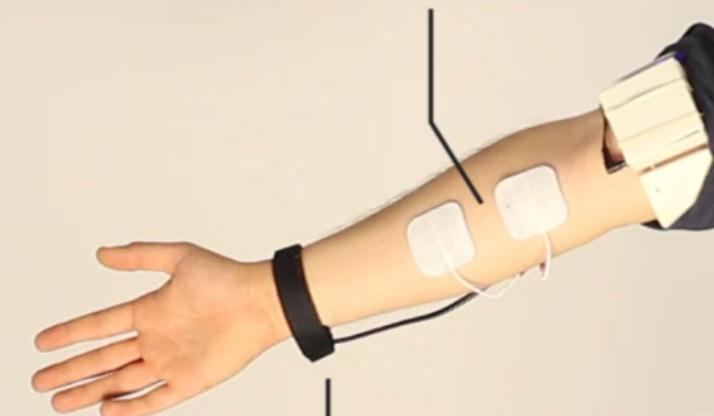






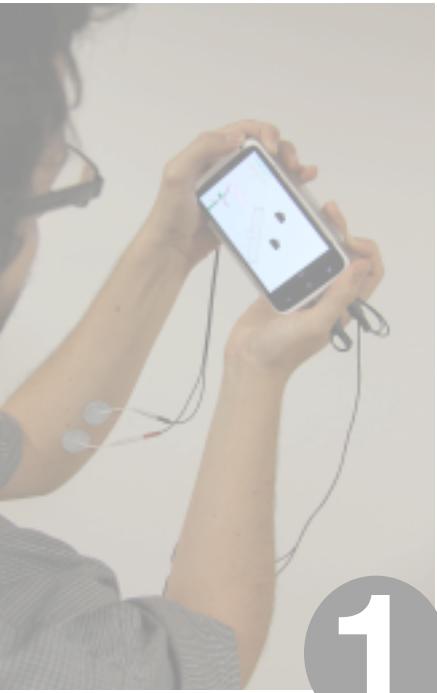


**electrical muscle stimulation**  
actuates the slaps



**microphone**  
senses hits and  
scores the player

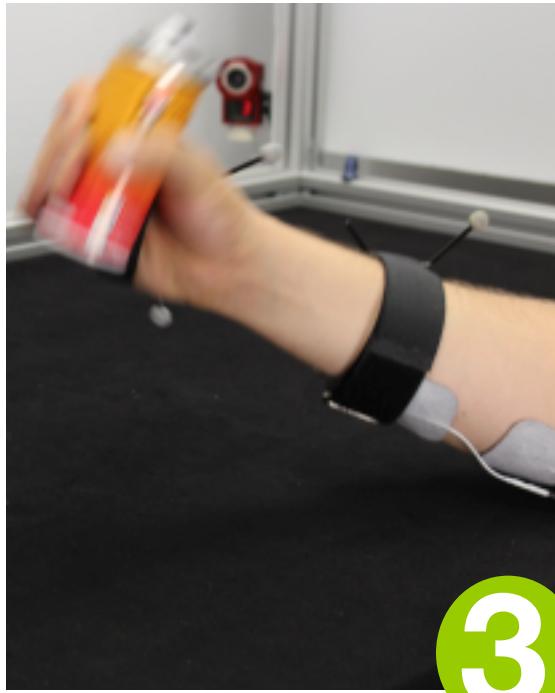
here is another asymmetric proprioceptive interaction.  
this "pong for one" game has a **spatial** component.



1



2



3

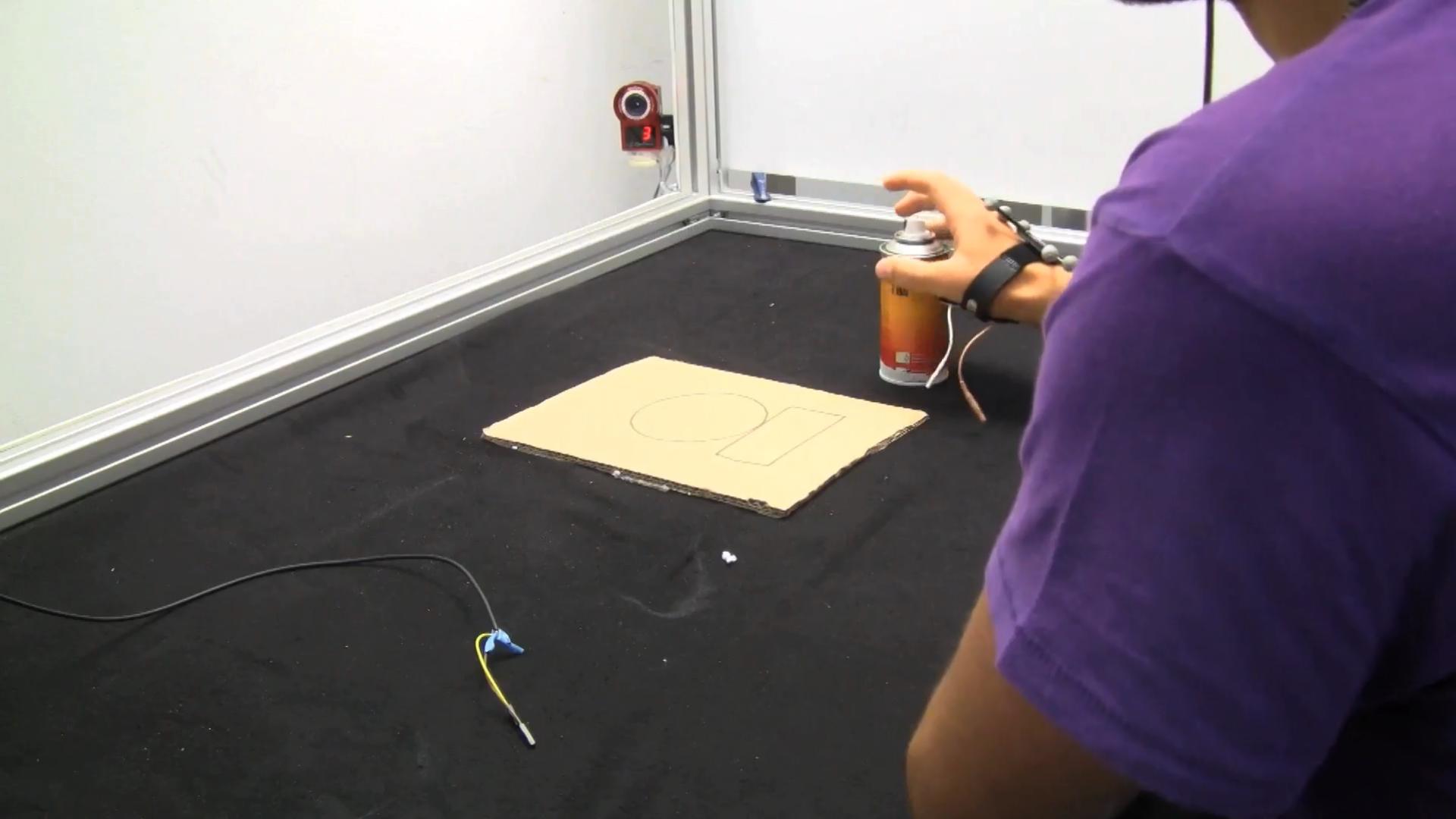


4

proprioceptive interfaces that r/w to the body

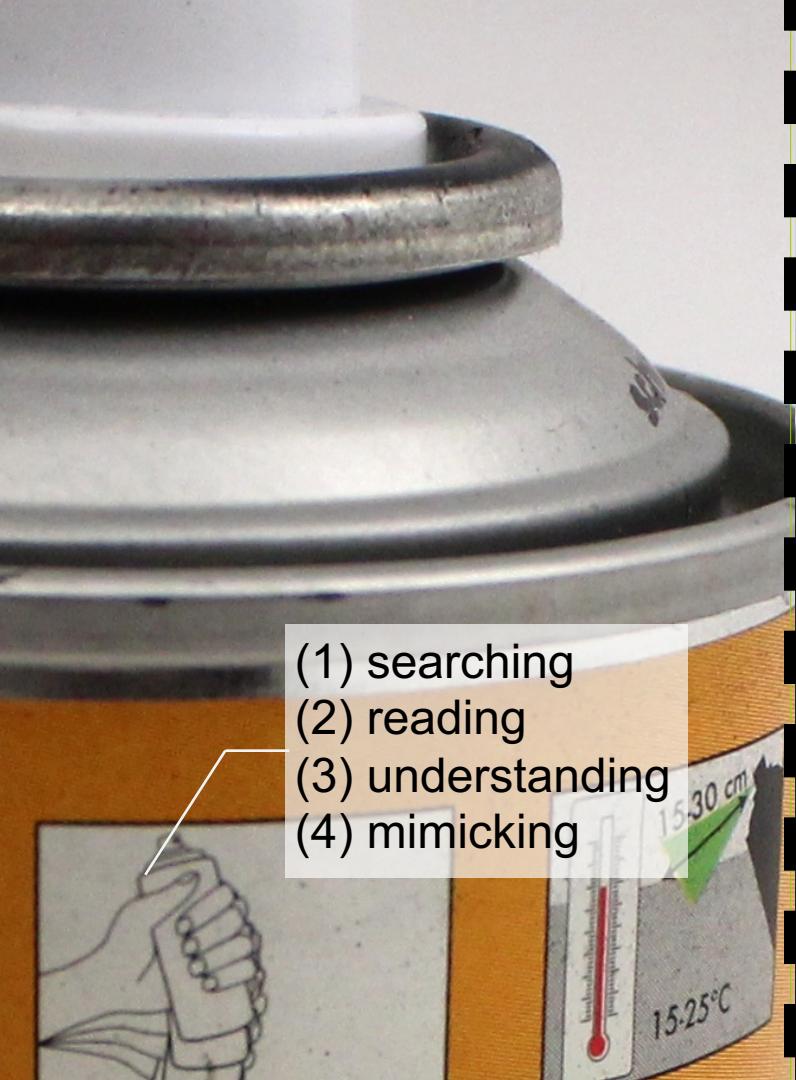
we asked participants to:  
paint this





# affordance++

allowing objects to communicate *dynamic* use  
(motion, multi-step processes, behaviors that change over time)  
by controlling *user* behavior.

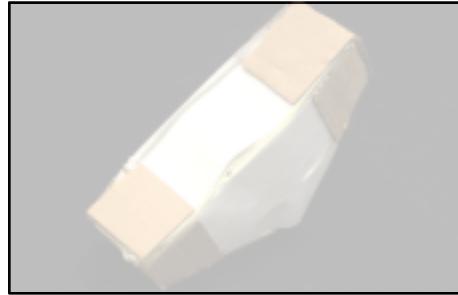
- 
- (1) searching
  - (2) reading
  - (3) understanding
  - (4) mimicking



the key is that the instruction (motion)  
happens and is perceived, at the same time

now the spray-can affords

1. what to do: shaking motion
2. the order of steps: grab, shake, spray
3. hidden state: e.g., throw away when empty



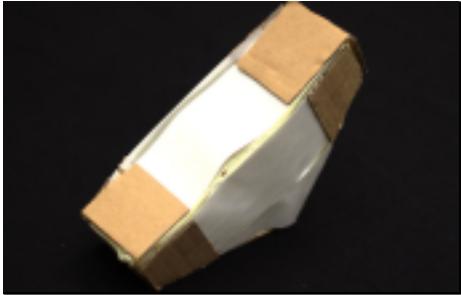
1. motion



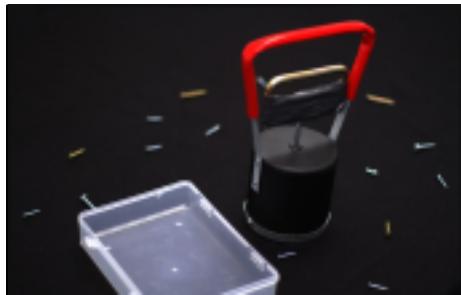
2. order of steps  
(multi-step processes)



3. hidden state



1. motion



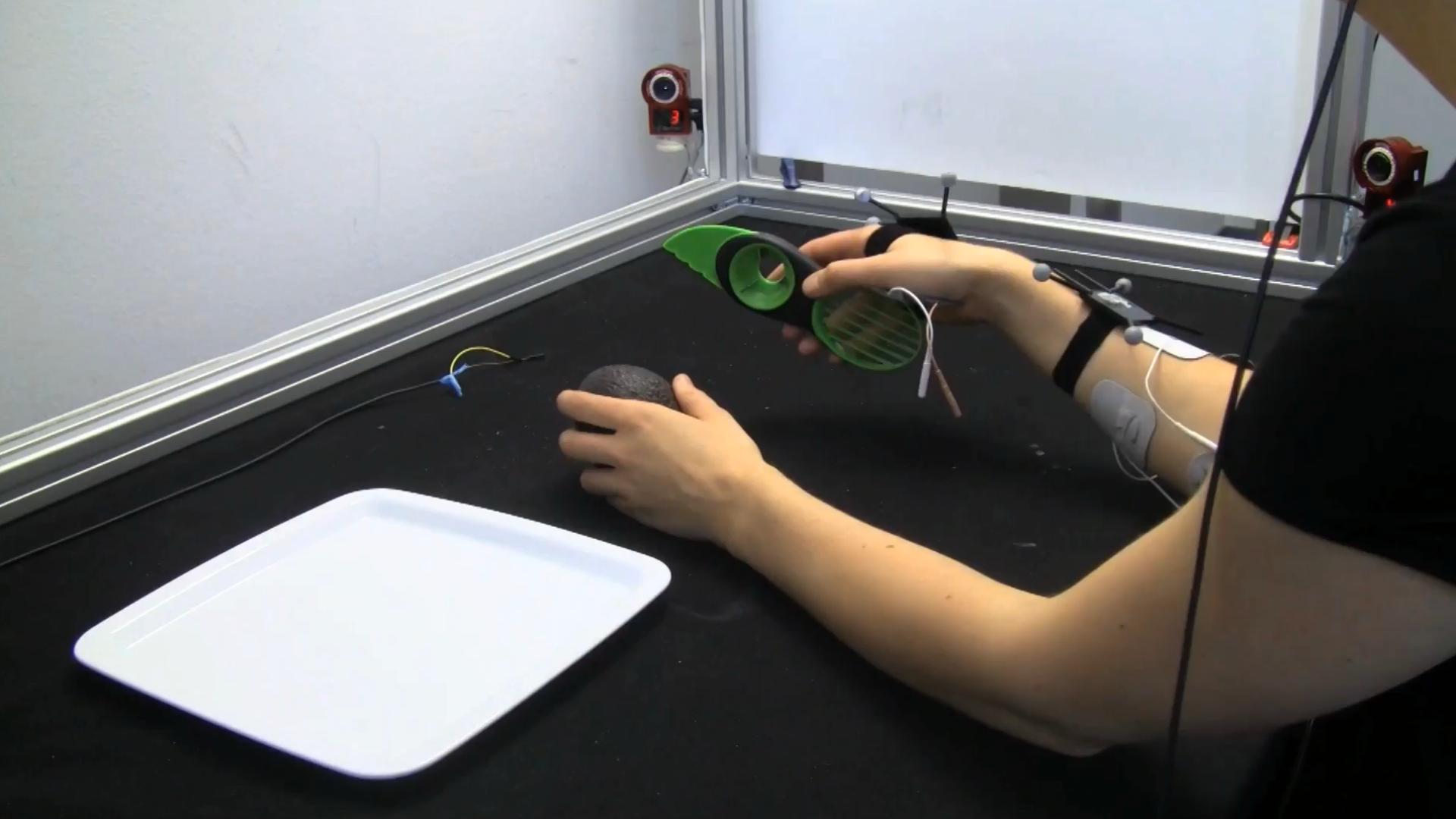
2. order of steps  
(multi-step processes)

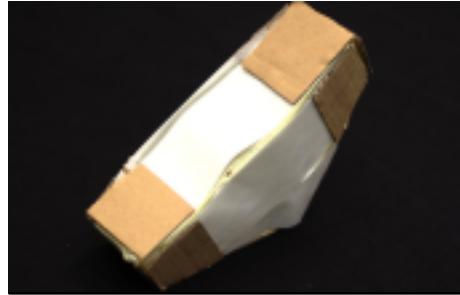


3. hidden state

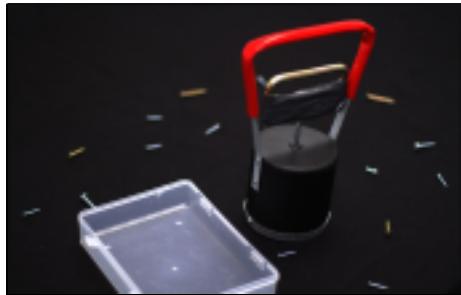
we asked participants to:  
prepare the avocado in thin slices







1. motion



2. order of steps  
(multi-step processes)



3. hidden state

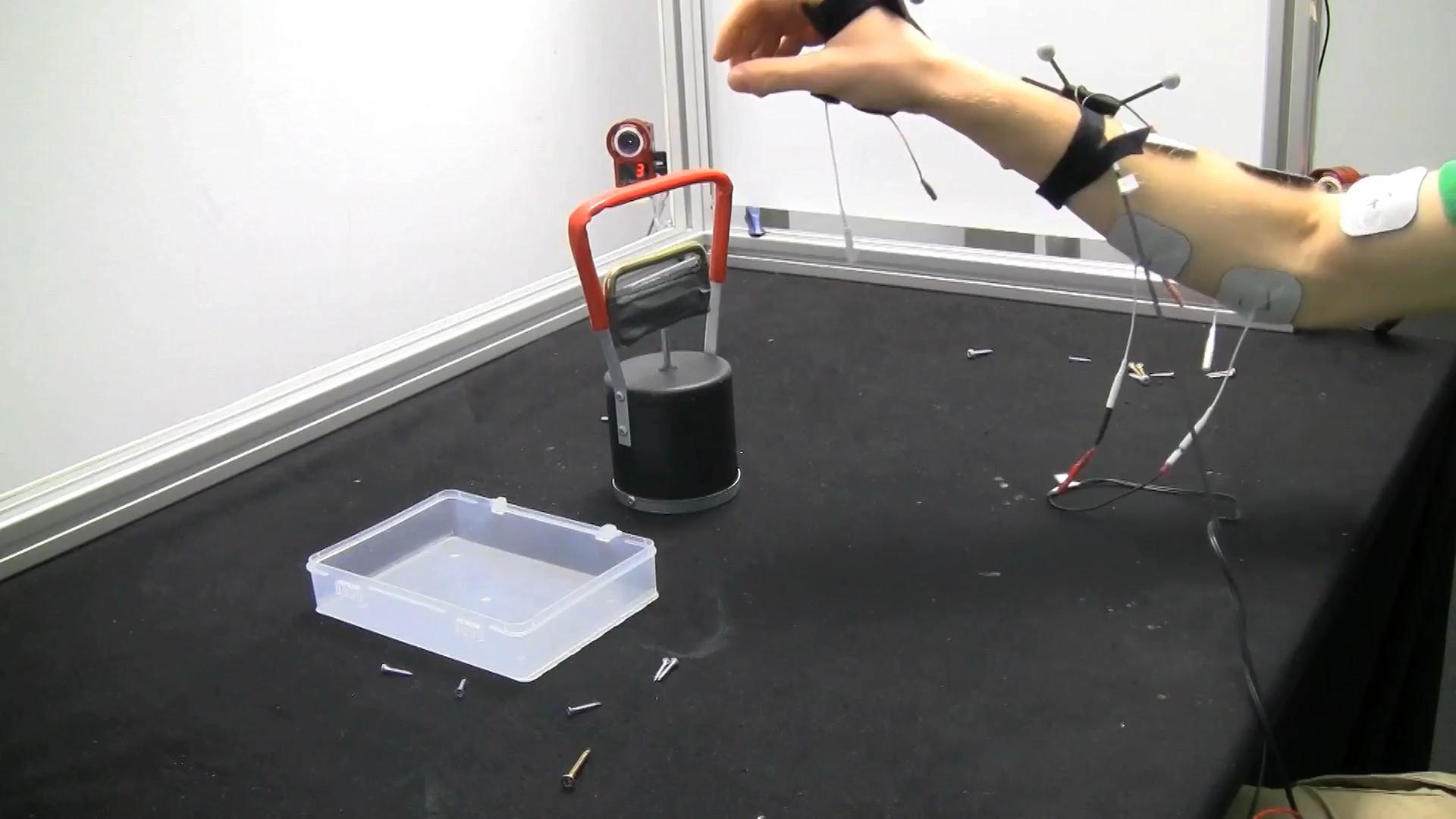
we asked participants to:  
**drink some water**





we asked participants to:  
collect all the screws



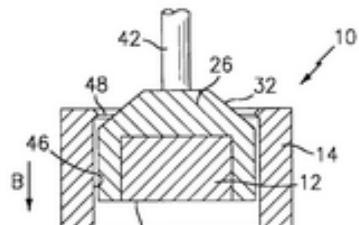
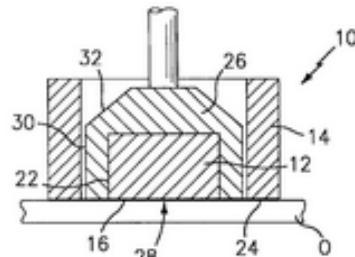


U.S. Patent

Aug. 31, 1999

Sheet 2 of 2

5,945,901



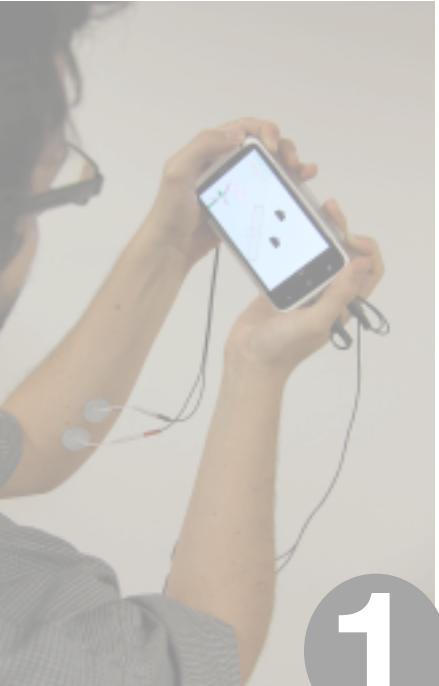
most users expect that pushing the handle is what grabs the nails,  
but that is the last step (releases)



we asked participants to:  
**drink some water**



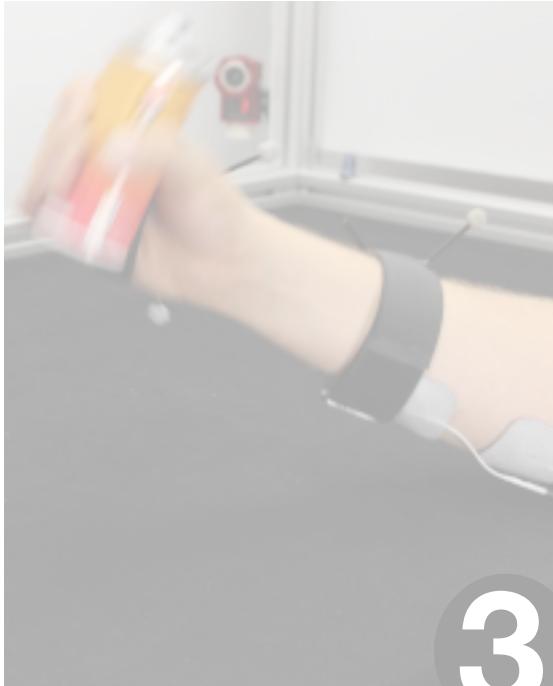




1



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4

proprioceptive interfaces that r/w to the body

output?



```
graph LR; TV[TV] --> Men[Two men]
```



but the output is not realistic, no motion

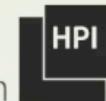
# impacto

Simulating Physical Impact by Combining  
Tactile with Electrical Muscle Stimulation



impacto, UIST'15

Pedro Lopes, Alexandra Ion, and Patrick Baudisch



Hasso  
Plattner  
Institut

a take away  
message



take away message

# **proprioceptive interaction**

is interacting through the pose of their own body (*proprius*).  
i.e., rather than seeing, hearing, or feeling an outside stimulus,  
users feel the pose of their body.

1. immersive: feel the virtual world on your body
2. interact eyes free & mobile
3. post wearable, i.e., body = I/O interface

we think this could be one approach to post-wearable:  
interfaces that fuse with the body



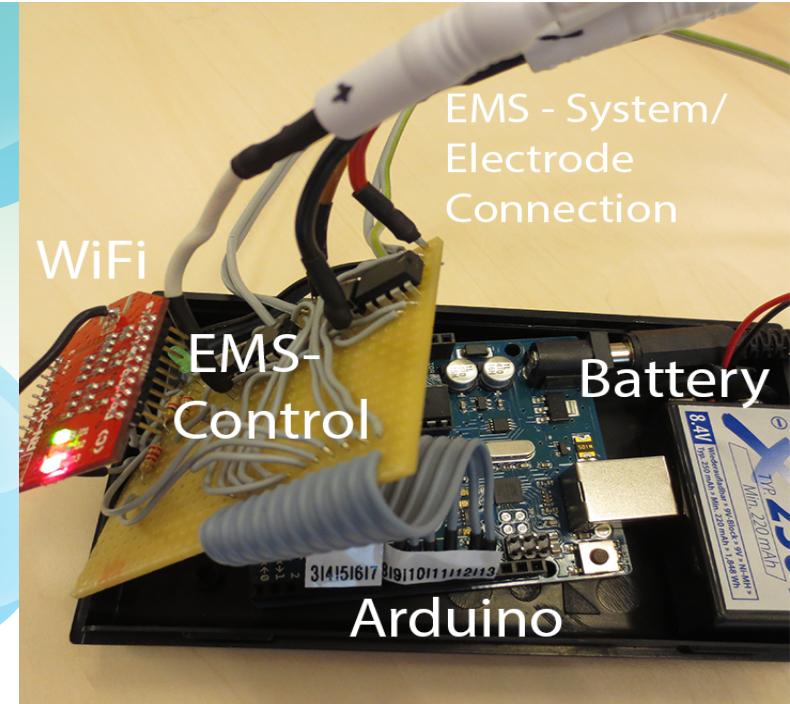
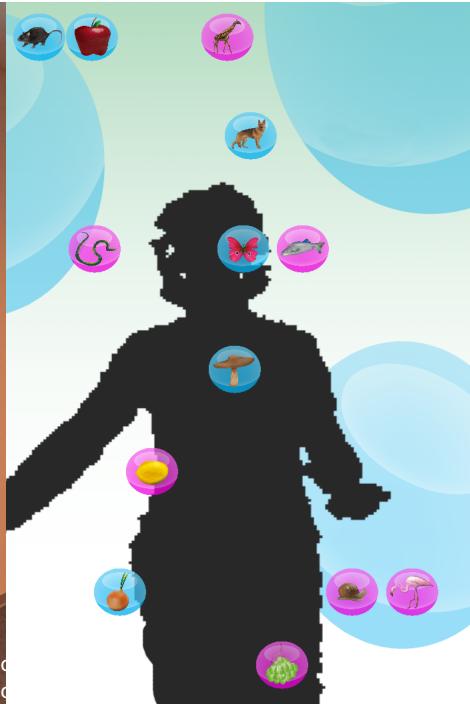
now.. max's work

# Max Pfeiffer

## Enabling Electrical Muscle Stimulation as Haptic Feedback



# Soap Babble Game: Supporting Interaction in Public Space with Electrical Muscle Stimulation



# Let Me Grab This:

## A Comparison of EMS and Vibration for Haptic Feedback in Free-Hand Interaction



M. Pfeiffer, S. Schneegass, F. Alt, M. Rohs:

Let me grab this: A comparison of EMS and vibration for haptic feedback in free-hand interaction.

In Proceedings of Augmented Human International Conference, 2014.

# A Design Space for EMS Feedback for Free-Hand Interaction

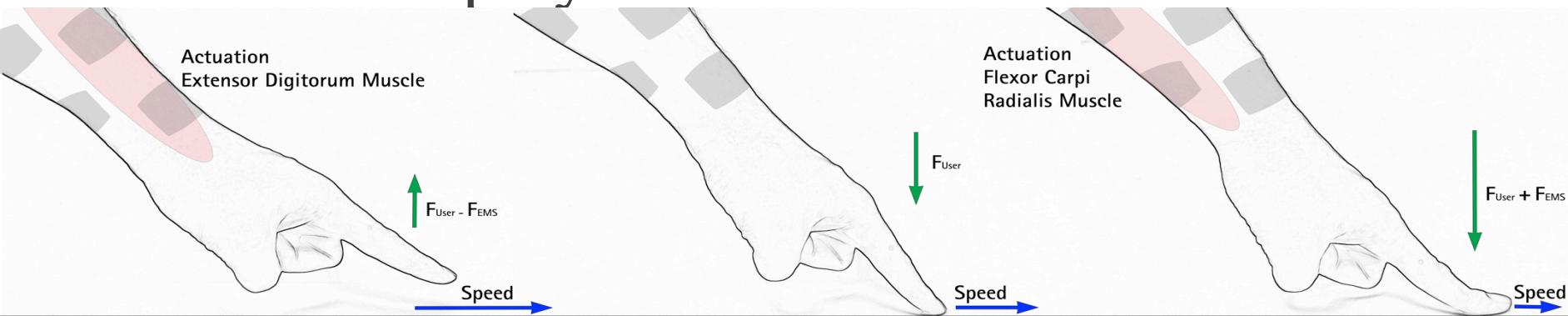


M. Pfeiffer, S. Schneegass, F. Alt, M. Rohs:  
A Design Space for Electrical Muscle Stimulation Feedback for Free-Hand Interaction.  
In Workshop on Assistive Augmentation – CHI, 2014.

# 3D Virtual Hand Pointing with EMS and Vibration Feedback

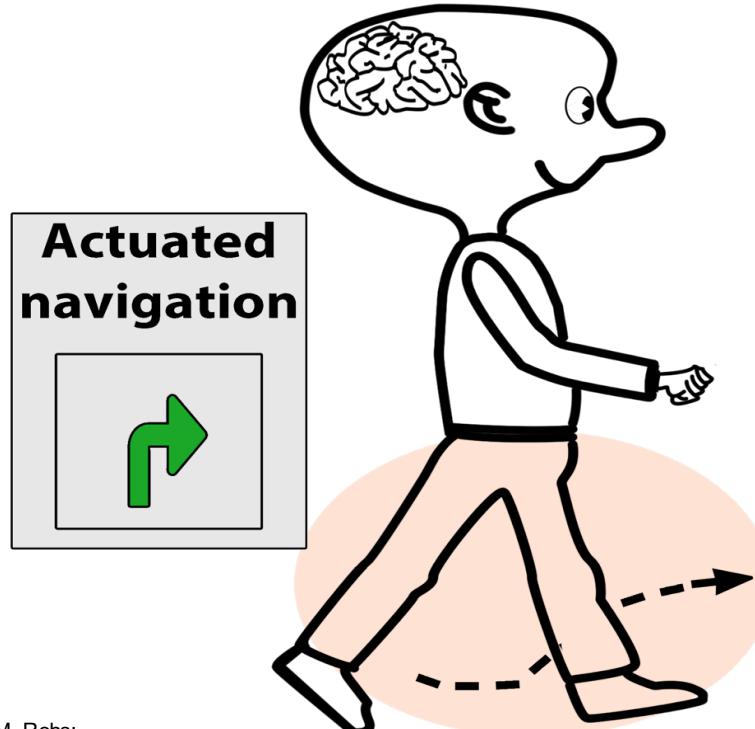


# Use Attached Haptic Feedback on Touch Displays



# Cruise Control for Pedestrians:

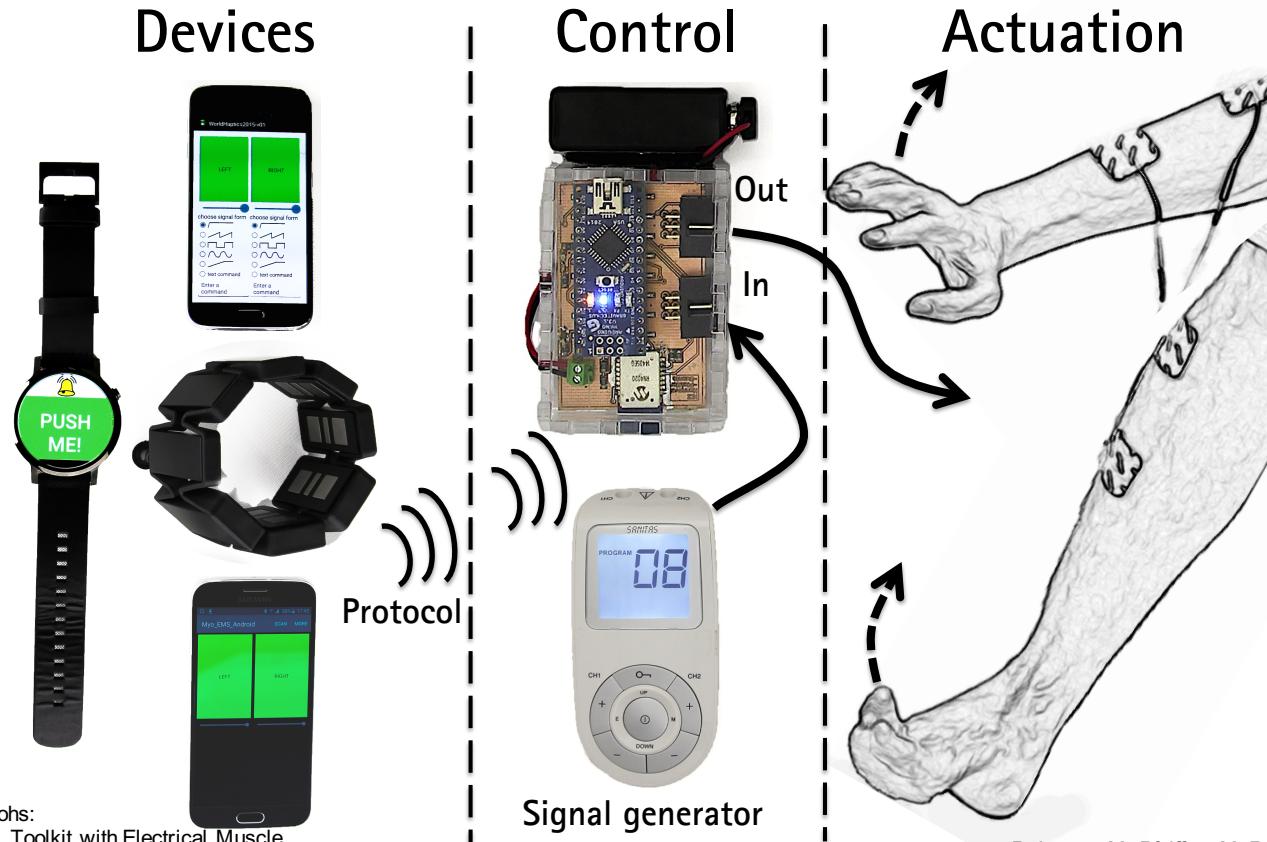
## Controlling Walking Direction using Electrical Muscle Stimulation



M. Pfeiffer, T. Dünte, S. Schneegass, F. Alt, M. Rohs:  
Cruise Control for Pedestrians: Controlling Walking Direction using Electrical Muscle  
Stimulation.  
In Proceedings of CHI, 2015.



# Let Your Body Move - Toolkit



M. Pfeiffer, T. Duente, M. Rohs:  
A Wearable Force Feedback Toolkit with Electrical Muscle  
Stimulation  
Submitted to: CHI, 2016 Interactivity.

P. Lopes, M. Pfeiffer, M. Rohs, P. Baudisch:  
Let your body move – a tutorial on electrical muscle stimuli as  
haptics.

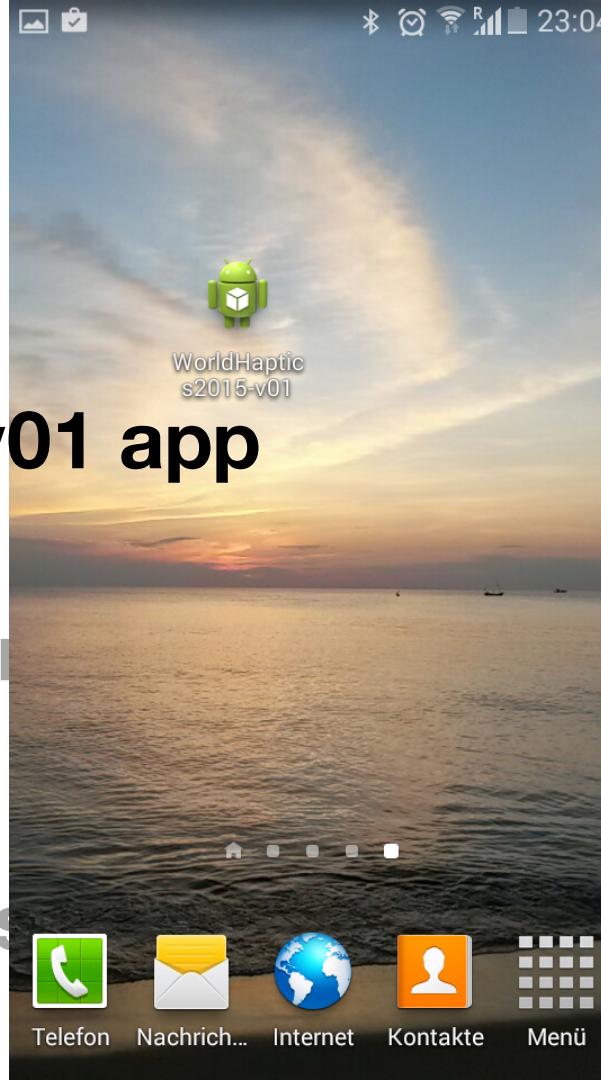
let's get started  
with EMS

**now, you will:**

- 1. get EMS + phone + board**
- 2. open the WorldHaptics2015-v01 app  
(desktop)**
- 3. power the control board with 9v battery  
(note don't power the EMS yet, no  
electrodes)**
- 4. connect the app to the board (board is  
running already)**
- 5. tap left/right to open channels**
- 6. great, control board works!**
- 7. now let's learn about EMS**

**now, you will:**

1. get EMS + phone + board
2. open the WorldHaptics2015-v01 app (desktop)
3. power the control board with (note don't power the EMS yet, no electrodes)
4. connect the app to the board running already)
5. tap left/right to open channels
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7. now let's learn about EMS

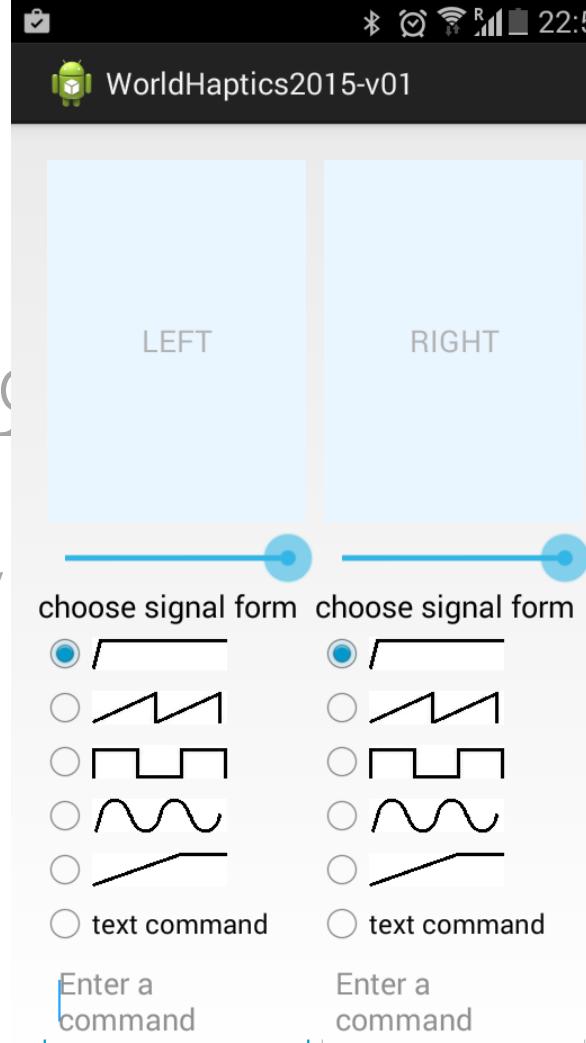


## **now, you will:**

1. get EMS + phone + board
2. open the WorldHaptics2015-v01 app  
(desktop)
- 3. power the control board with 9v battery +  
wait 10s (don't power the EMS yet, no  
electrodes)**
4. connect the app to the board (board is  
running already)
5. tap left/right to open channels
6. great, control board works!
7. now let's learn about EMS

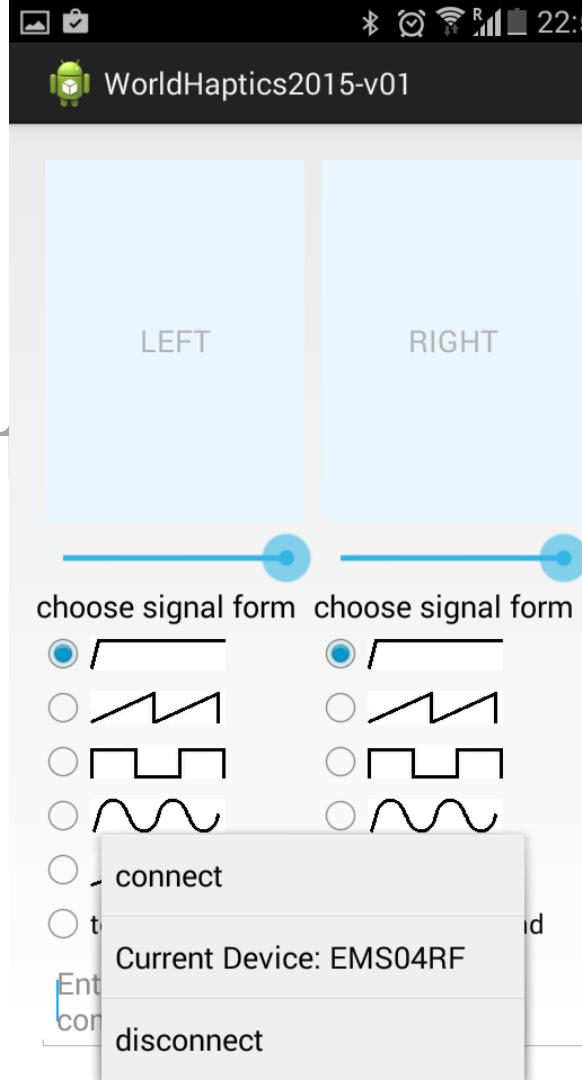
**now, you will:**

1. get EMS + phone + board + elec
2. open the WorldHaptics2015-v01 (desktop)
3. power the control board with 9v (note don't power the EMS yet, no
4. connect the app to the board (board is running already)
5. tap left/right to open channels
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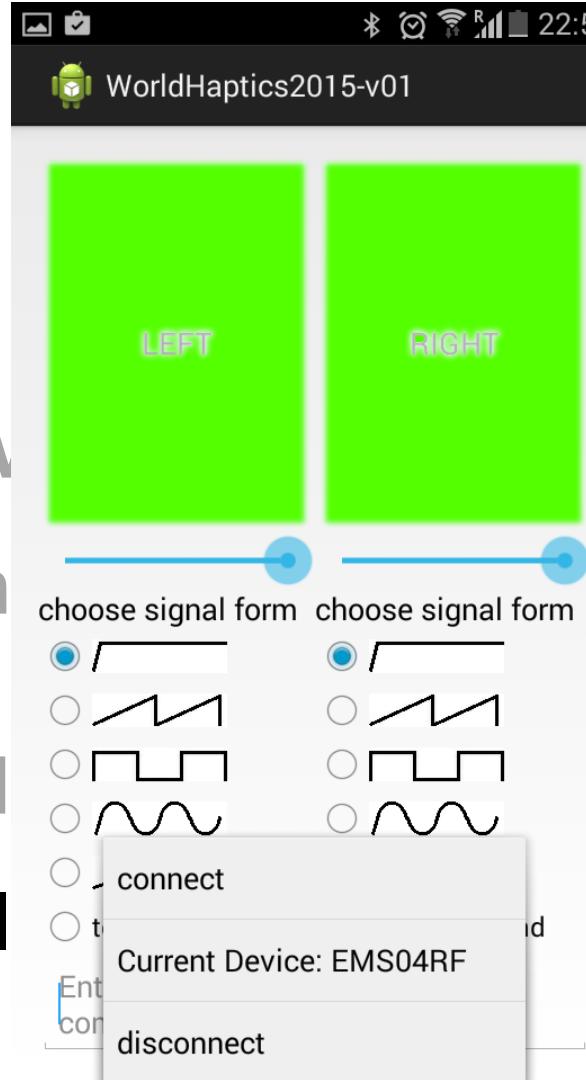
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**now, you will:**

1. get EMS + phone + board
2. open the WorldHaptics2015-v01 (desktop)
3. power the control board with (note don't power the EMS yet, electrodes)
4. connect the app to the board running already)
5. **tap left/right to open channel**
6. great, control board works!
7. now let's learn about EMS



## **now, you will:**

- 1. get EMS + phone + board**
- 2. open the WorldHaptics2015-v01 app  
(desktop)**
- 3. power the control board with 9v battery  
(note don't power the EMS yet, no  
electrodes)**
- 4. connect the app to the board (board is  
running already)**
- 5. tap left/right to open channels**
- 6. if you see LEDS, great, control board  
works!**

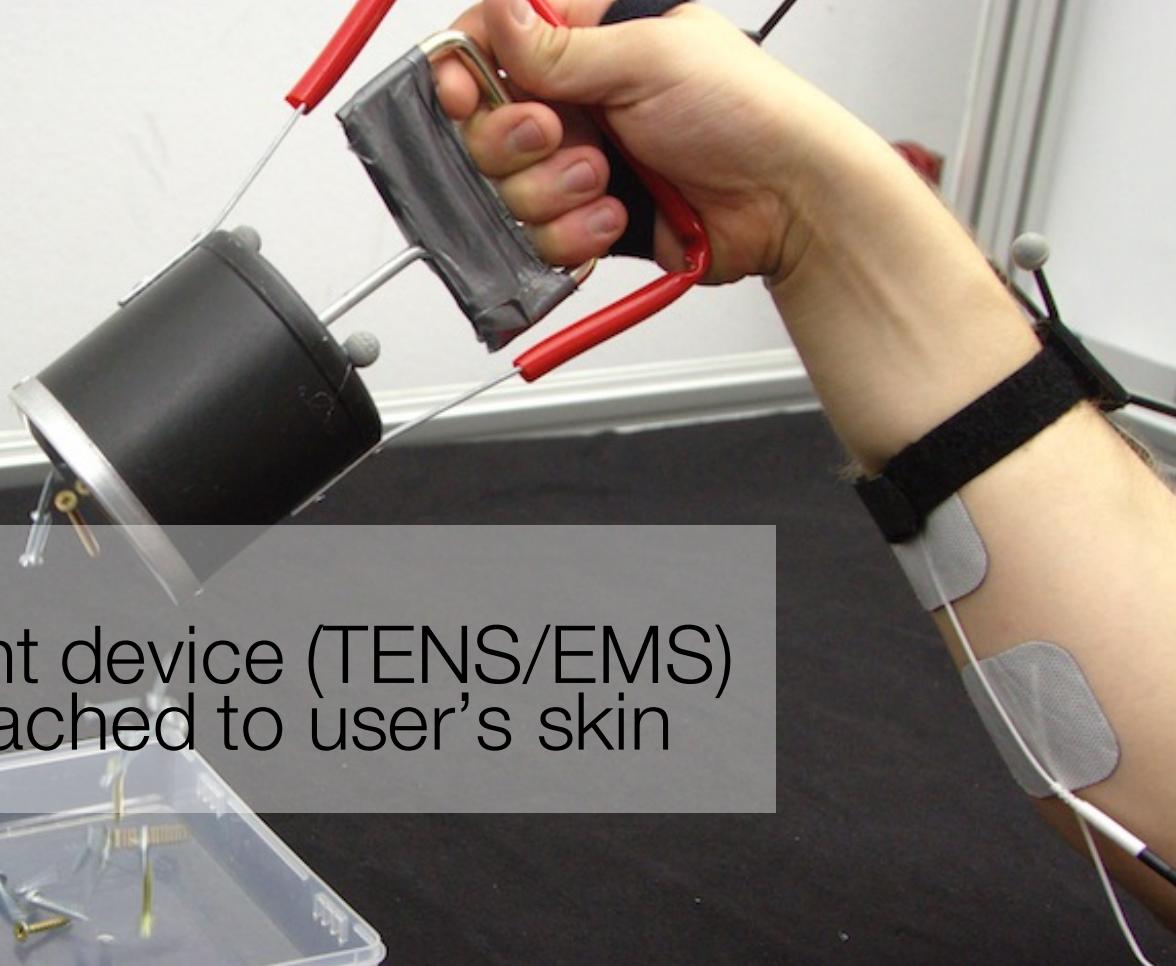
## **now, you will:**

- 1. get EMS + phone + board**
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- 3. power the control board with 9v battery  
(note don't power the EMS yet, no  
electrodes)**
- 4. connect the app to the board (board is  
running already)**
- 5. tap left/right to open channels**
- 6. if you see LEDS, great, control board  
works!**

a word on safety

basics of EMS are:

- medically compliant device (TENS/EMS)
- two electrodes attached to user's skin



EMS uses electrical impulses to stimulate nerves and muscle fibers. Here are the golden rules:

0. Never put electrodes across the heart.
1. Electrodes on the same side of the body.
2. **Electrodes must be close**, no electrodes more than a few centimeters away.
3. always place electrodes first, then start EMS.  
**Do not readjust electrodes with EMS on.**

Actually EMS machines are designed to prevent situations such as an EMS pad that falls off, still..

## 0. prevention is the best safety measure

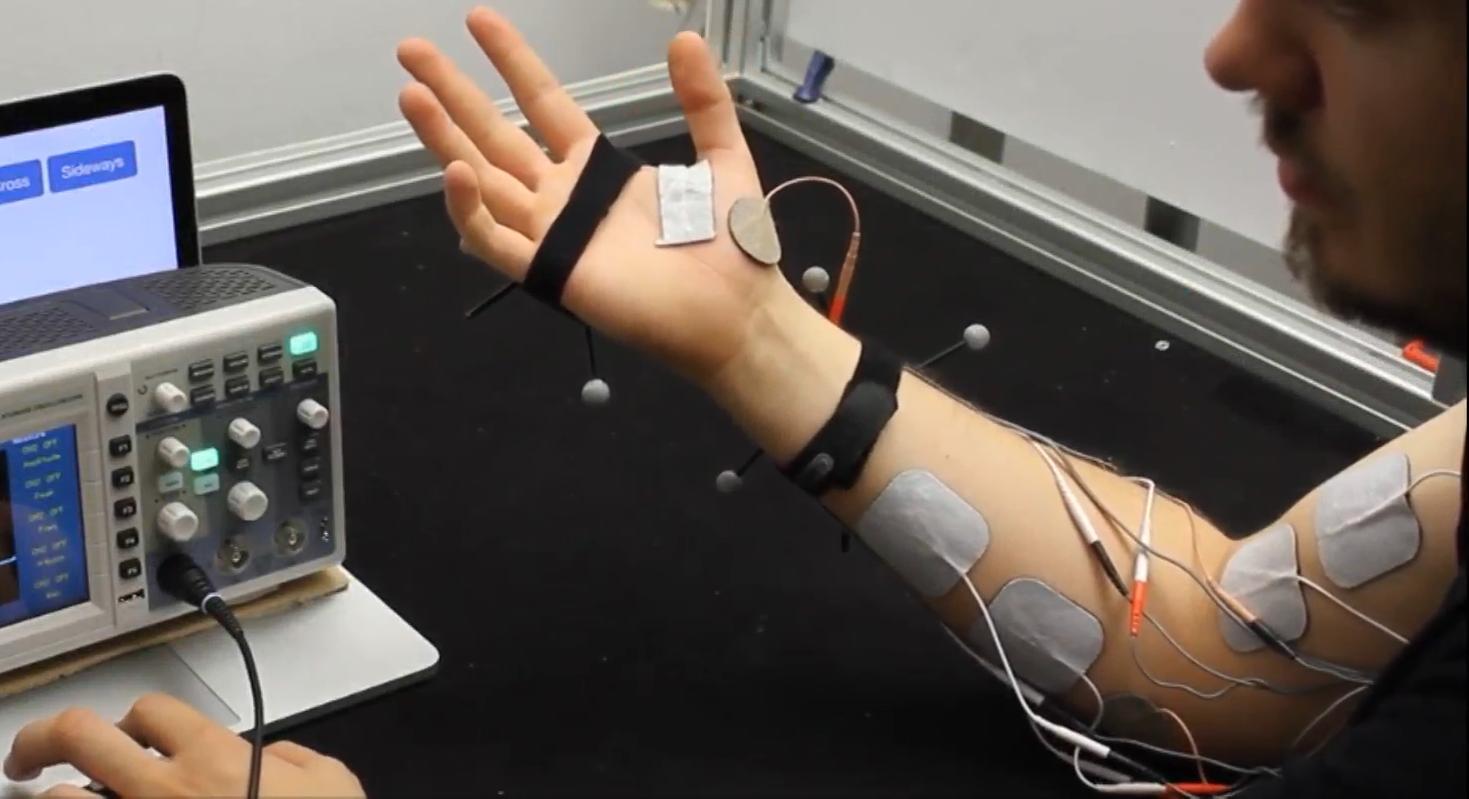
How do machines protect you if a pad falls off?

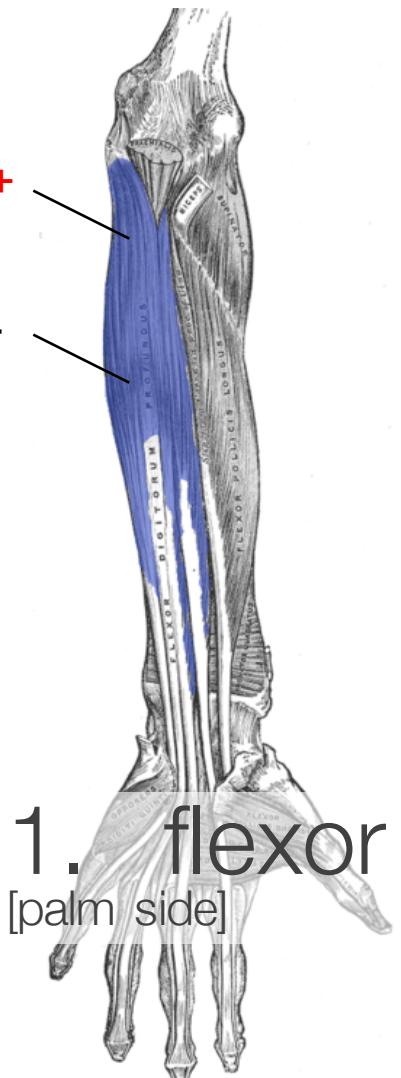
1. analog solution: parallel small resistor
2. digital solution: test pulse prior to EMS pulse

# muscular anatomy

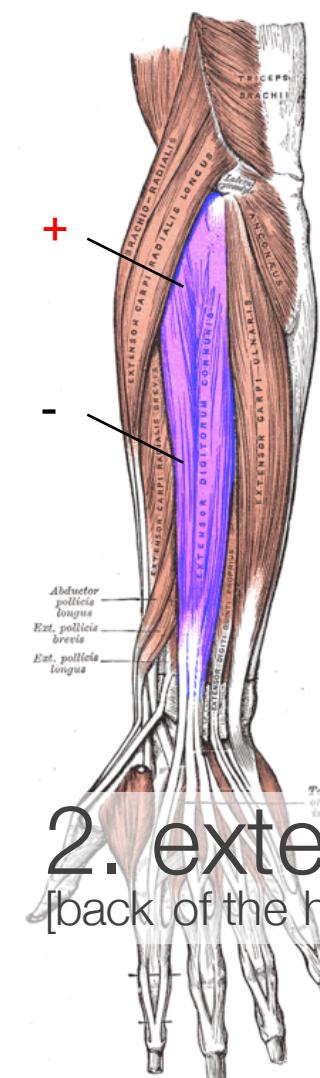
to make your life easier, here are a few muscles that are easy to actuate:

1. palm/wrist flexor
2. palm/wrist extensor
3. biceps
4. calves
5. leg turning





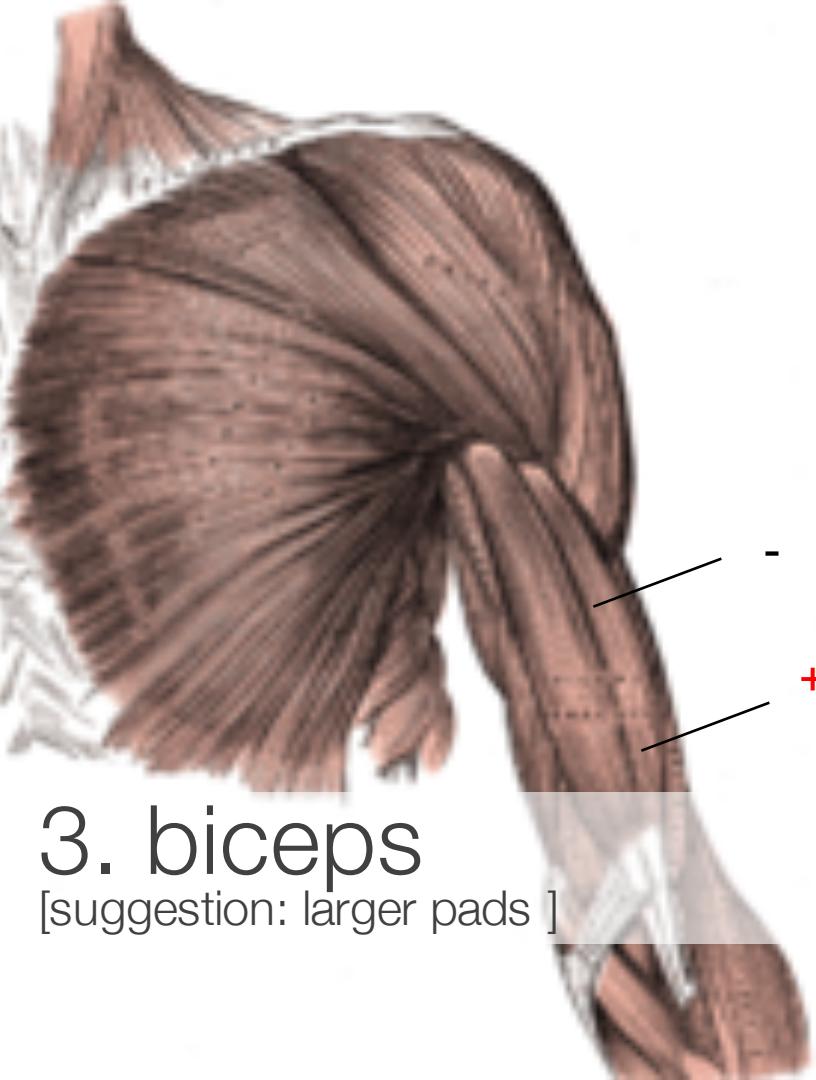
1. flexor  
[palm side]



2. extensor  
[back of the hand]



2. extensor

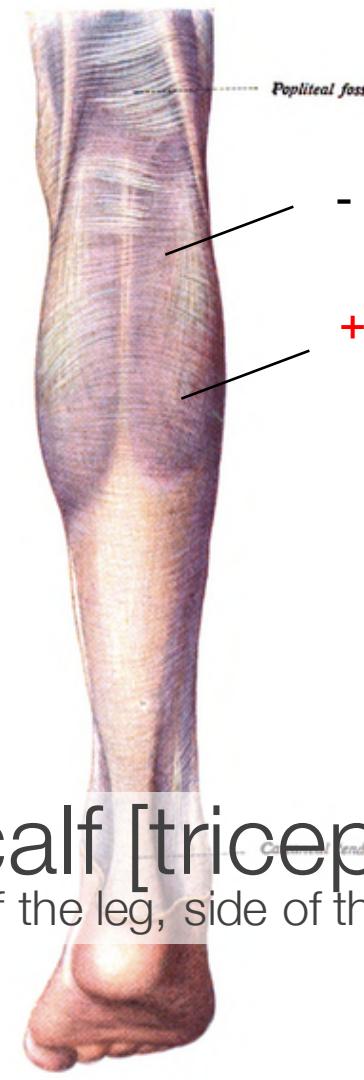


### 3. biceps

[suggestion: larger pads ]

### 4. calf [triceps surae]

back of the leg, side of the heel, large pads]



let's start trying the EMS out!

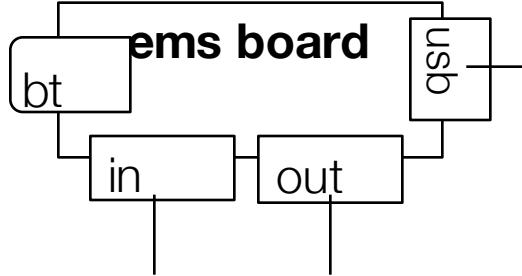
0. get the EMS hardware
1. get the smartphone
2. pair them together
3. locate the palm/wrist flexor
4. place electrodes with EMS off
5. call us to check position
6. calibrate first, on the max level (& pain-free)
7. let's try it as a wizard of oz device!

exploring EMS

break into groups and let's brainstorm what novel interaction does your EMS system allow:

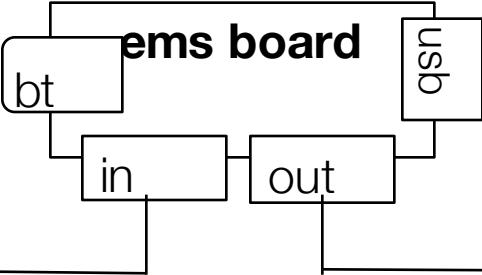
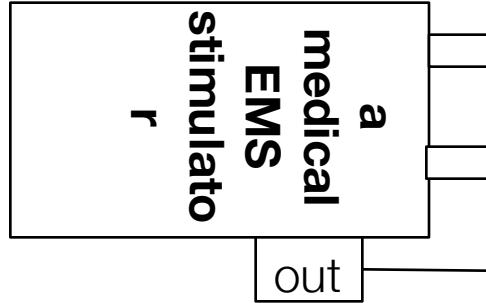
- feeling/transmitting force
- assistive systems
- transmitting information
- haptics for games
- haptics for virtual reality
- your own idea!

interfacing with our  
EMS control board



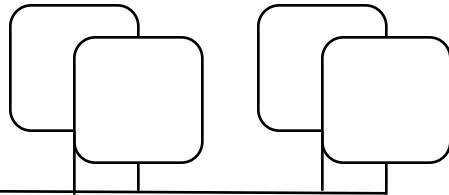
the EMS board accepts commands via bluetooth 4.0 (low energy) or serial (USB).

there is an on-board arduino, running the code to modulate the EMS amplitude according to the command received.

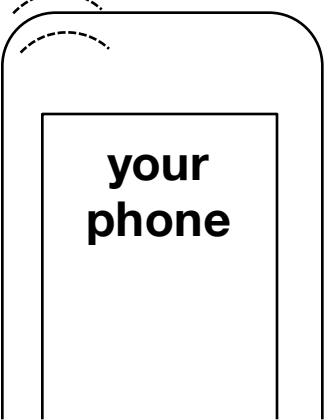


channel 1  
electrodes

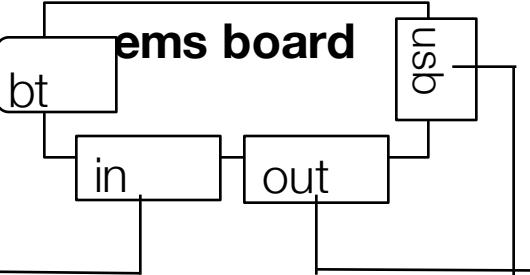
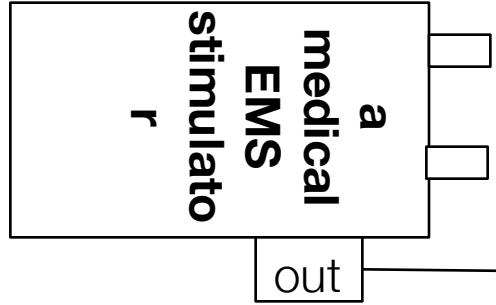
channel 2  
electrodes



or virtually  
any  
bluetooth  
device

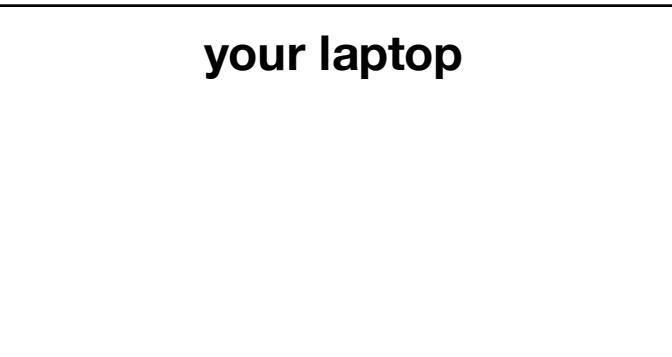
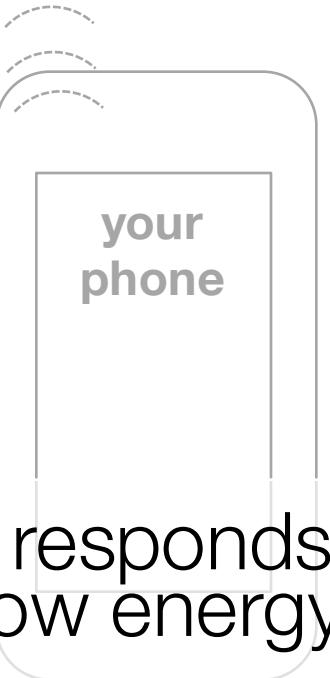
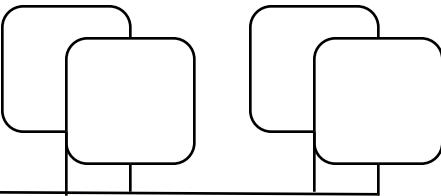


the EMS board responds to commands via  
bluetooth 4.0 (low energy)



channel 1  
electrodes

channel 2  
electrodes



or virtually  
any  
bluetooth  
device

the EMS board responds to commands via  
bluetooth 4.0 (low energy) or serial (USB).

# credits

course Materials and Slides by Pedro

EMS board designed by Max & Tim

software by Max & Tim, edits by Pedro

casings by Pedro & Doga

software and Hardware under MIT License (no military use) see LICENSE.

further  
related work



eyes-free wearable output (vibrotactile)



increase expressiveness (vibrotactile arrays)

[Huang et. al, CHI'10]

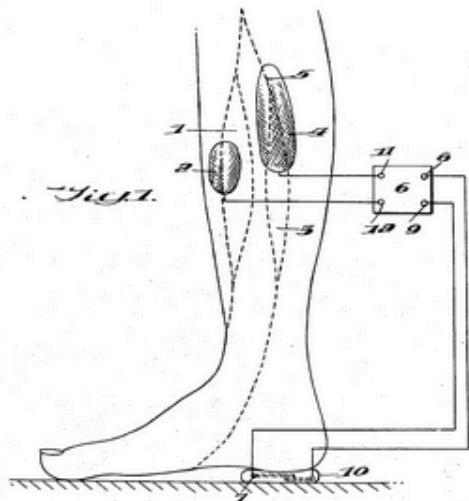


input and output, unified (gesture output)

Oct. 3, 1967

F. F. OFFNER ET AL  
METHOD OF MUSCULAR STIMULATION IN HUMAN  
BEINGS TO AID IN WALKING  
Filed Jan. 13, 1965

3,344,792



[Liberson et. al, Patent '67]  
[Vodovni et al, Prosthetics '77]

**rehabilitation** based on EMS, since the 60's

# PossessedHand

EMS as **training** system

[tamaki & rekimoto, CHI'11]



EMG interfaces for **muscle input** [saponas et al., CHI'10]

exit(0);