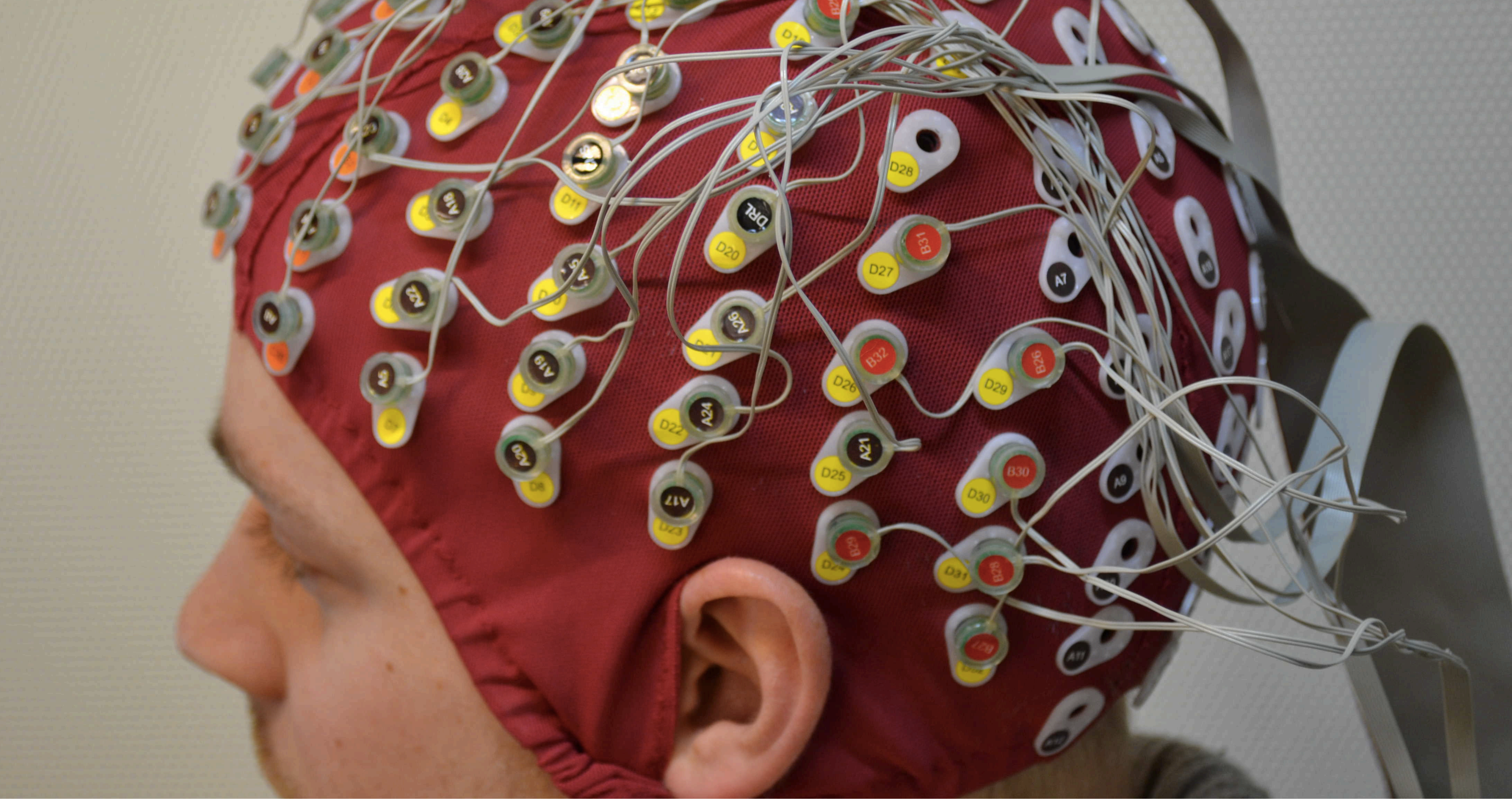


# Brain Computer Interfaces

## 6.S063 Engineering Interaction Technologies

Prof. Stefanie Mueller | HCI Engineering Group

# the body as an interface::

- brain computer interfaces
- muscle computer interfaces
- implanted interfaces

# #1

## brain computer interfaces

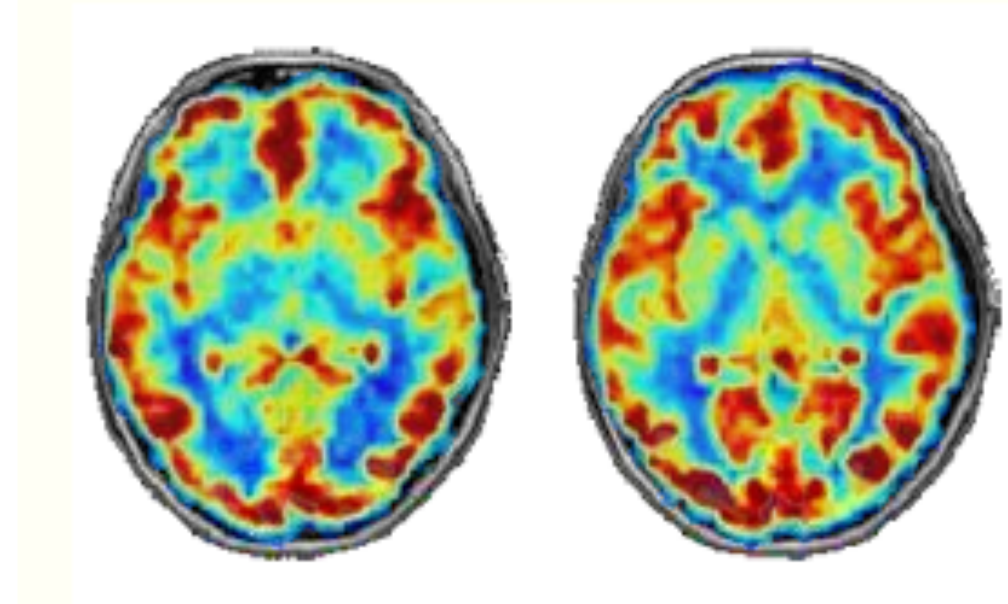
# brain computer interface ::

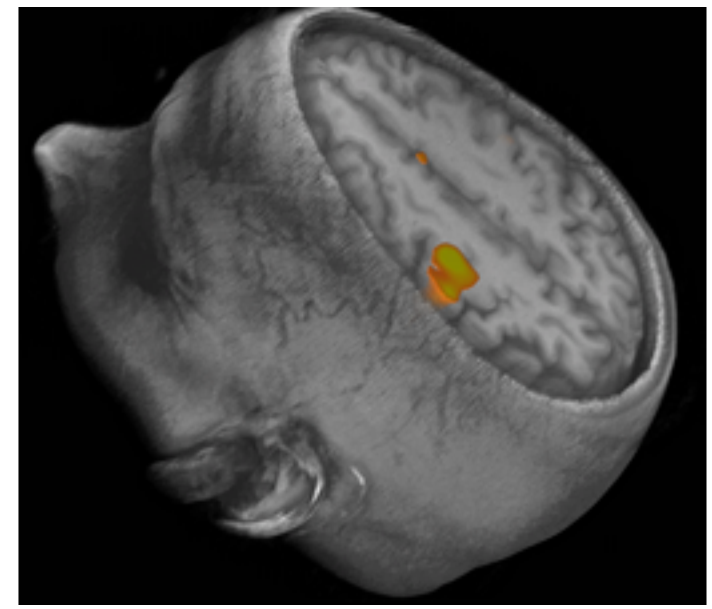
interacting directly using **"thought"**

what does that even mean?

# sensing the brain::

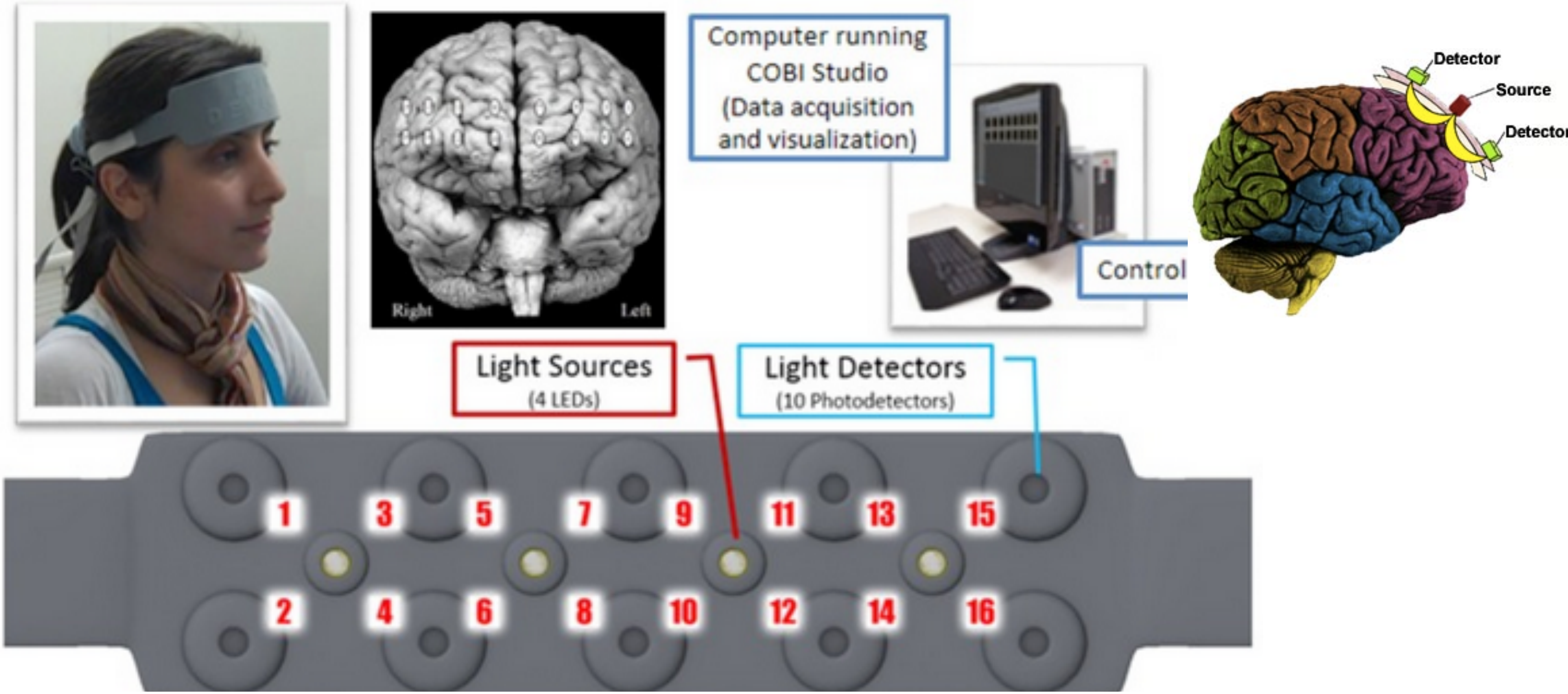
- **EEG** (electroencephalography)
- **fNIRS** (functional near-infra-red spectroscopy)
- **fMRI** (functional magnetic resonance image)



# fMRI (magnetic resonance):

- blood flows in the brain
- blood becomes more **oxygenated when neural activity increases**
- oxygen-rich and -poor blood have different **magnetic properties**
- measure magnetic field changes in the brain




# fNIRS (near infrared-spectroscopy):

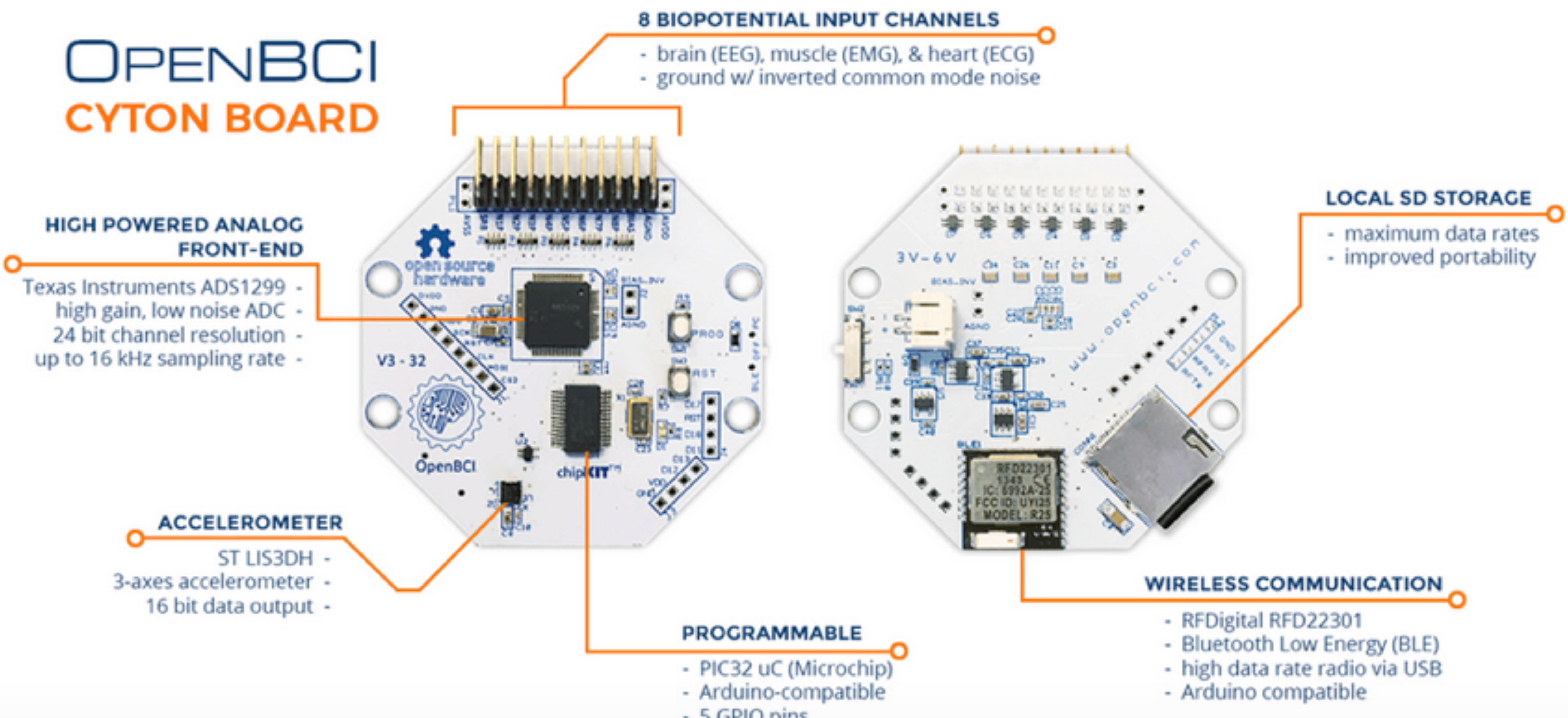
- optical, changes in absorbed light of the near-infra-red spectra
- same principle as fMRI but optical:
- more blood flow and more oxygen -> more absorption of light
- mean penetration depth: ca. 23mm (depends on wavelength and sensor position on head)


# EEG (electroencephalography):

- electric activity: neurons communicate with electrical impulses
- measuring **neurons firing in the brain to exchange signals**
- electrodes on the head measure the electric field

# DEMOCRATIZING NEUROTECHNOLOGY

| | | |
|---|---|---|
| Low-Cost BCI Hardware | EEG/EMG/ECG Monitoring | 3D Printed EEG Headsets |
| High Quality Brain Imaging | Electrodes & Adaptors | A Global Community |
| Learning Materials | Biosensing & Neurofeedback Tools | Realtime Brain, Muscle, Heart Monitoring |



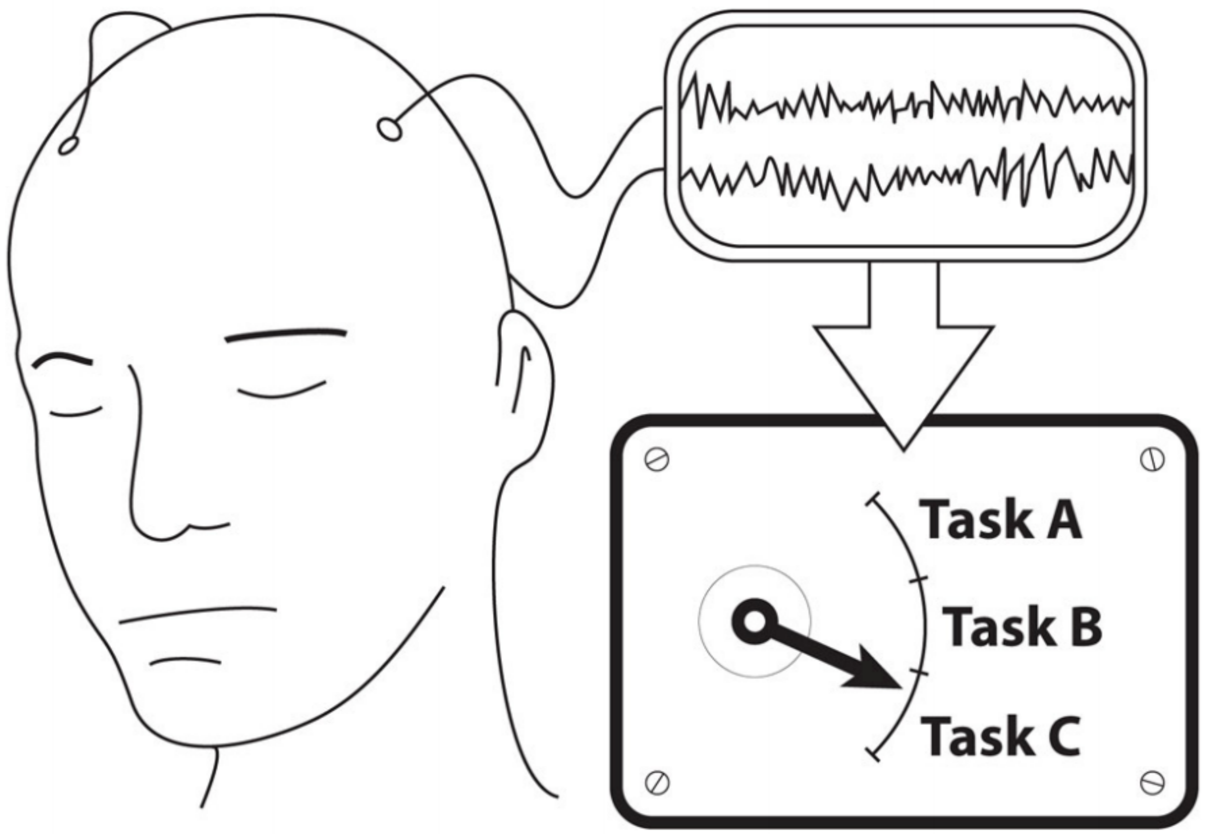
## sensing the brain::

- **EEG** (electroencephalography)
- **fNIRS** (functional near-infra-red spectroscopy)
- **fMRI** (functional magnetic resonance image)

so are we really measuring **thoughts?**

**<30s brainstorming>**

**no,** we **measure signals**
and **extract features** from them.




and then **match the result** with
a certain task (or ‘thought’)
(based on known training data)

when did BCI research start?

1924: Hans Berger: first human EEG (but no real time analysis)

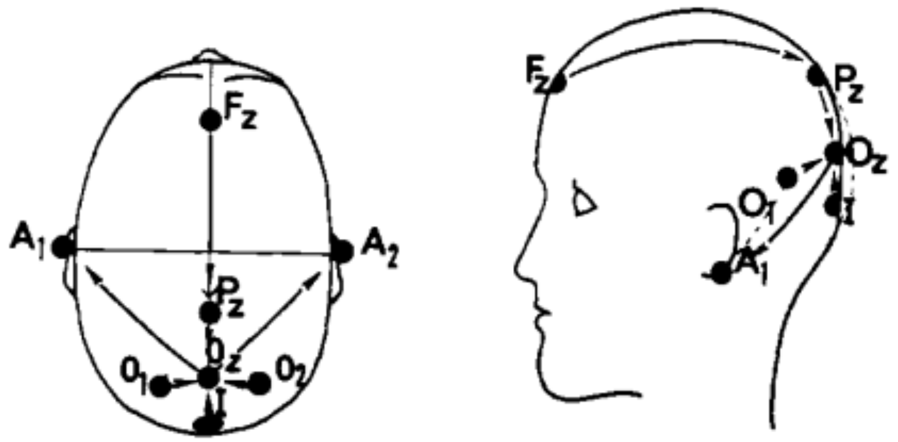


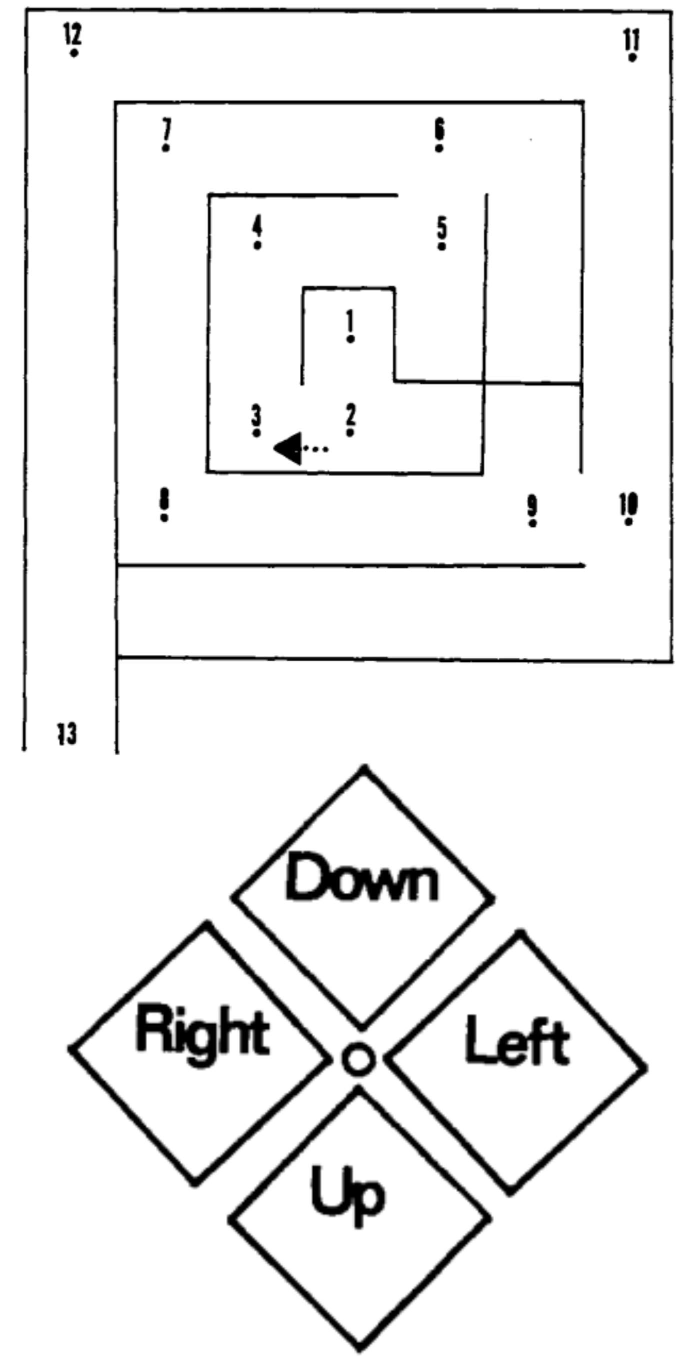

Fig. 3. Electroae locations in pattern experiments. Electrodes are applied at five scalp locations and to the connected ears. The ERP data is collected from the occipital and parietal areas with four bipolar channels: $P_z$-$O_z$, O1-$O_z$, O2-$O_z$, $I$-$O_z$ and one monopolar channel (to the ear reference): $O_z$-$A$. The frontal electrode is used for artifact detection only ($F_z$-$P_z$).

The experiment campaign conducted in our laboratory with visual evoked responses involved single epoch classification in real-time, i.e., the identification for each epoch of the value or class of the input stimulus. Stimulus parameters included flash intensity and color, background intensity and color (retinal adaptation) and finally pattern shape. The real-time paradigm in every case lead to a nontrivial elaboration of the experiment design.

## IV. Example of Experiment Design

One of these experiment series, dealing with parafoveal pattern stimuli, will be briefly described here to illustrate the general paradigm.

Subjects are seated in a shielded room, in front of a multiple



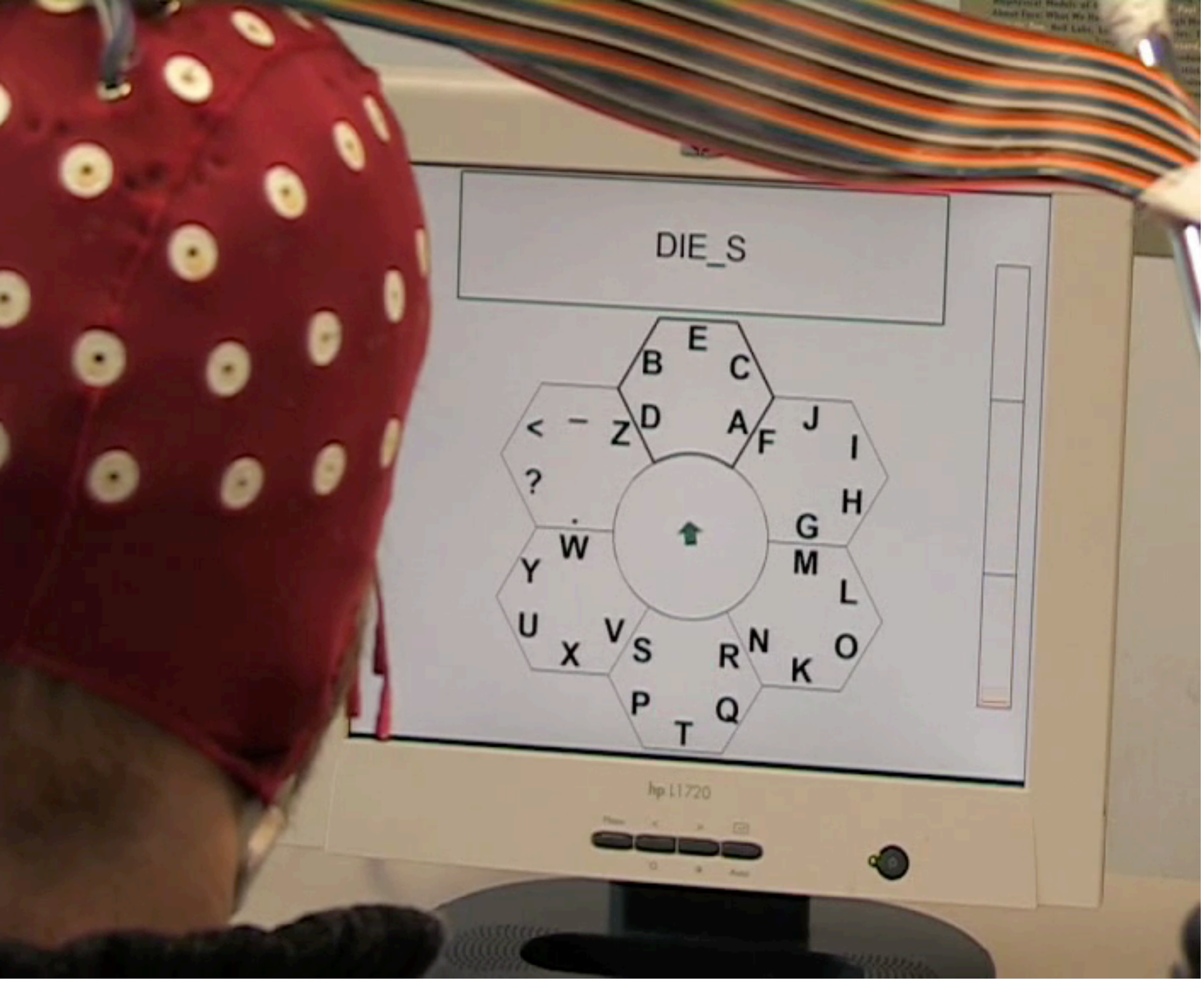

(b)

Fig. 4. Stimulus target in real-time visual ERP experiments. The target consists of a fixed diamond shaped red cherckerboard illuminated with a xenon flash to provide visual stimulation. (a) The four

## 1977: Jaques Vidal ‘Real-time detection of brain events in EEG’

latest progress in imaging of the brain::

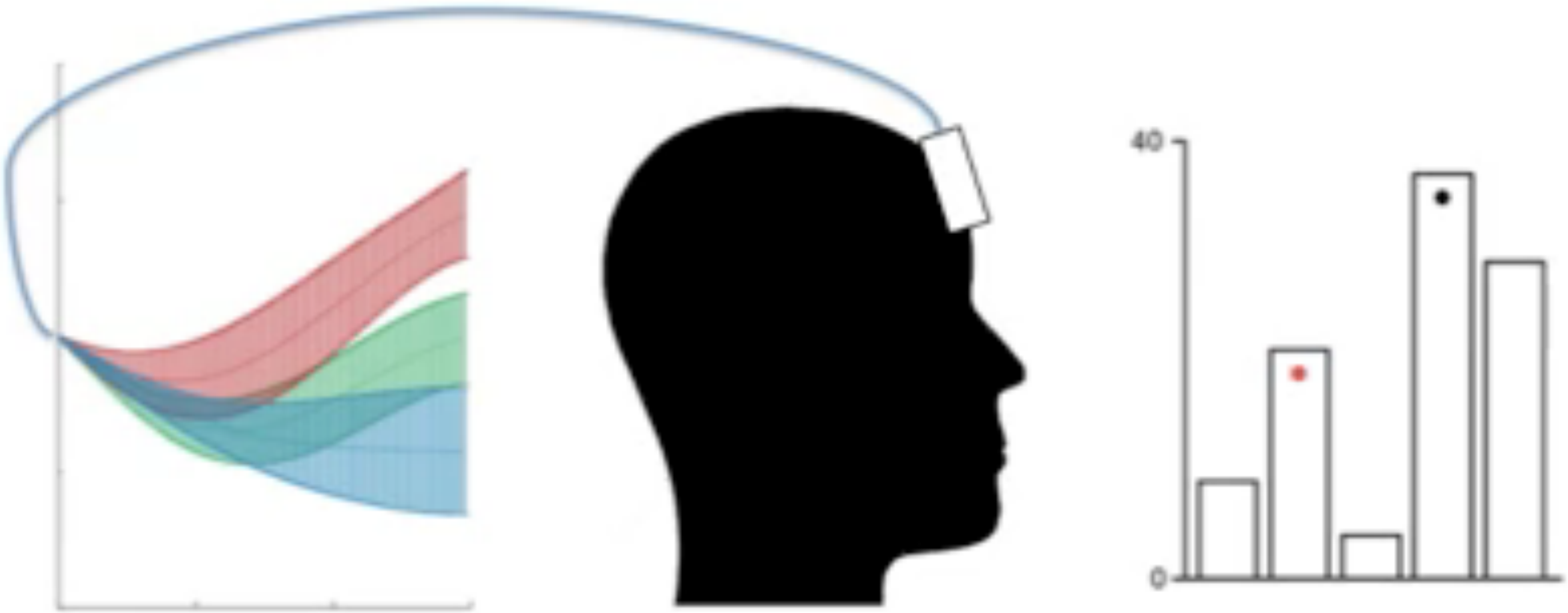
so what can we **use** brain sensing for **today?**




## helping people with **disabilities**

Samek et al. Stationary Common Spatial Patterns for Brain-Computer Interfacing, Journal Neural Engineering '12.

# Using fNIRS Brain Sensing to Evaluate Information Visualization Interfaces





Evan M Peck . Beste F Yuksel . Alvitta Ottley

Robert JK Jacob . Remco Chang

Tufts UNIVERSITY

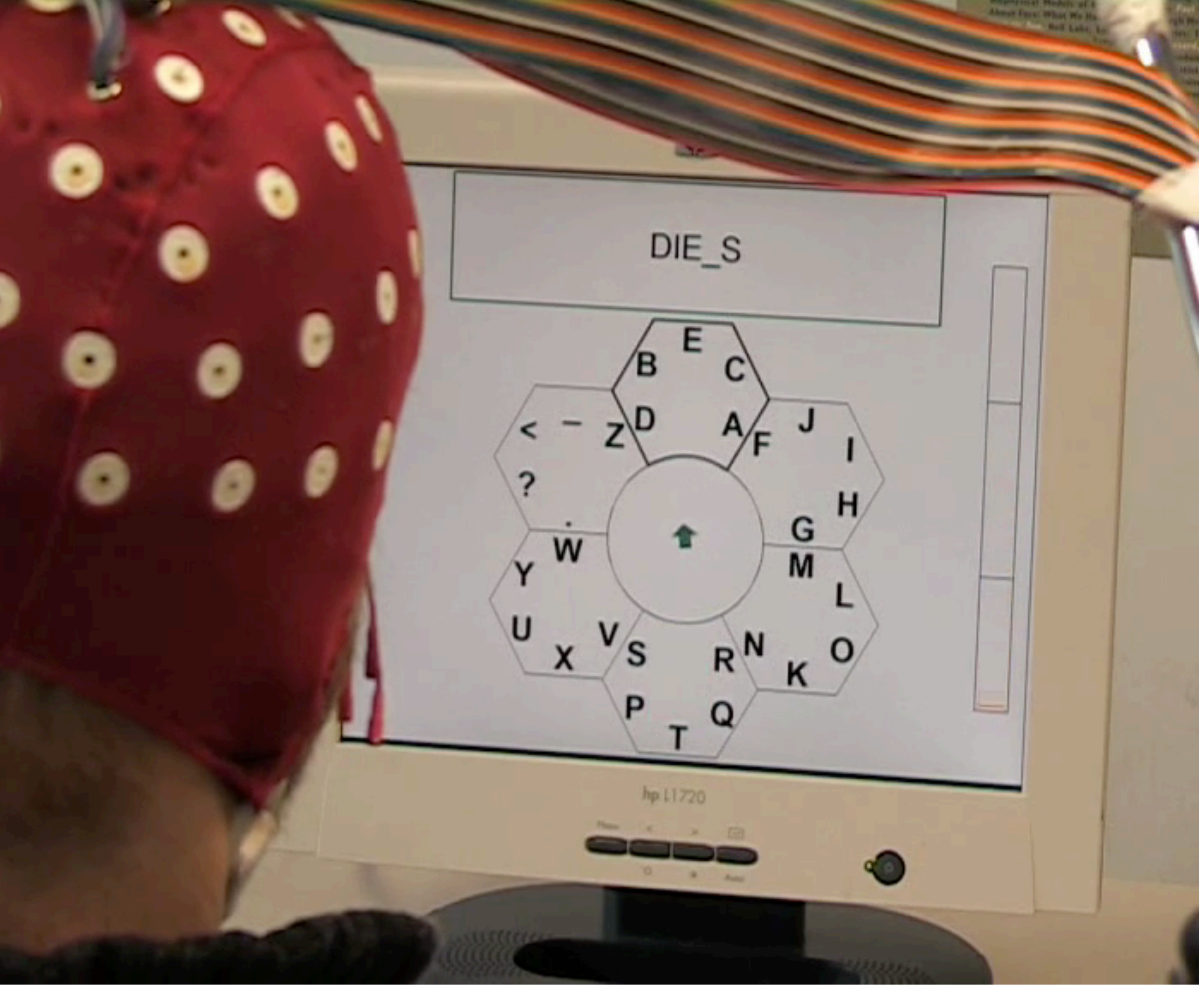

**user interface evaluation:**

more direct feedback than when interviewing users

Evan Peck. Using fNIRS Brain Sensing to Evaluate Information Visualization Interfaces, CHI’13

games and entertainment

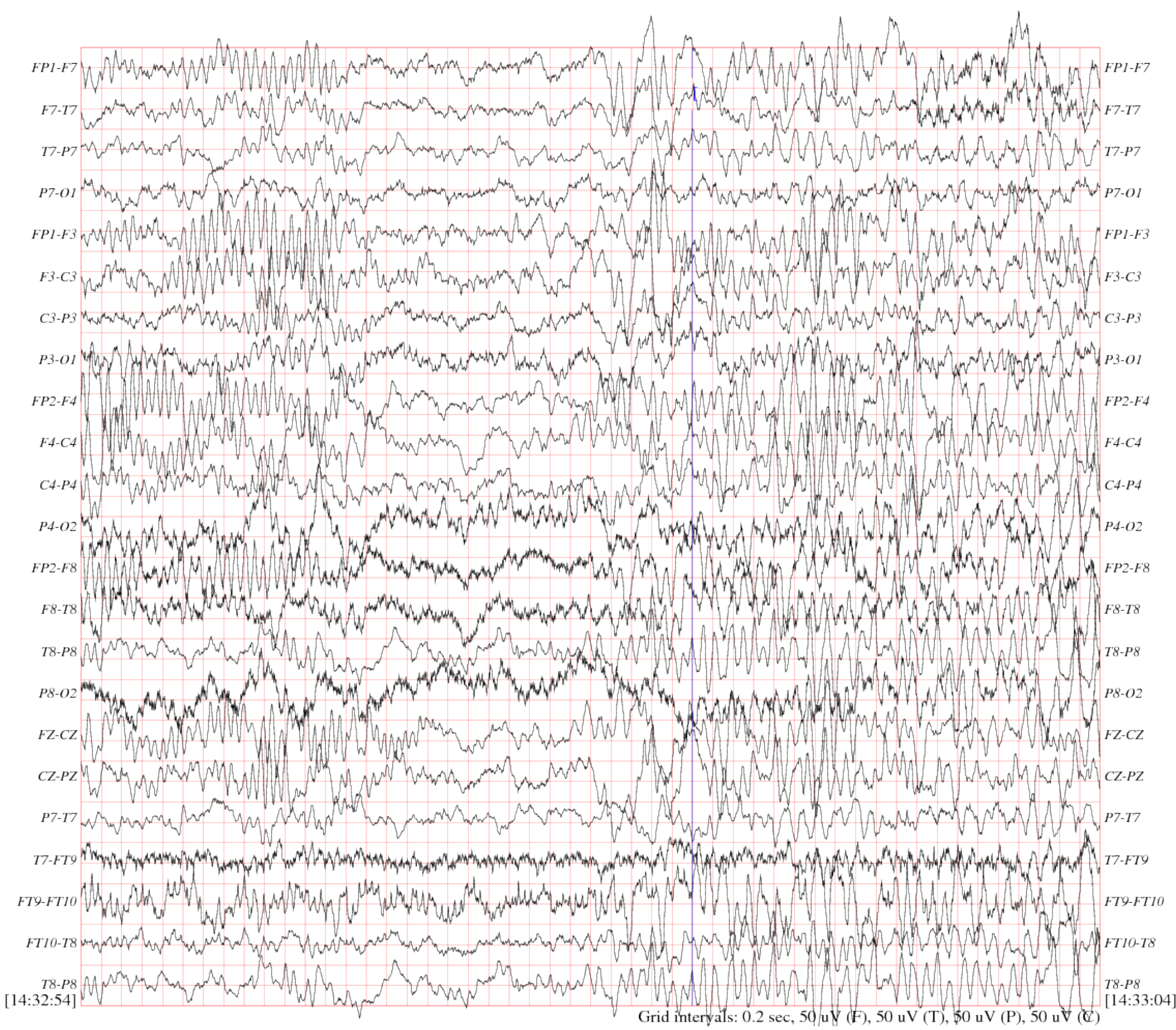
some problems with BCI…



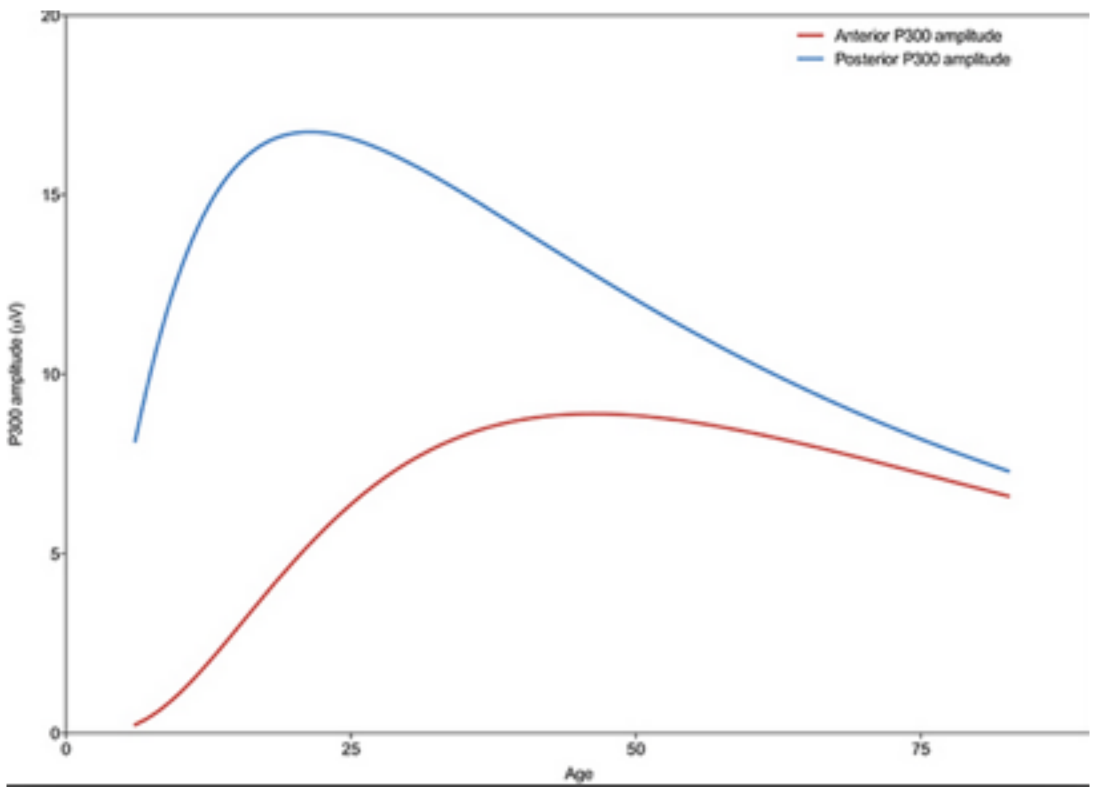

so **slow?**
what is the problem here?

**<30s brainstorming>**

**electrodes** = camera of the brain
**one electrode** = one pixel




you **need a lot of data**
to find a good signal
('collection over time')




# p300 signal::

- when you make a (subconscious) decision, there is a very strong signal
- why p300? latency between stimulus and response is ca. 300 ms

if BCI worked perfectly,
would we use BCI for all interaction?

**<30s brainstorming>**

**motionless:** nothing wrong with moving

**affordance:** gestures are (very) natural

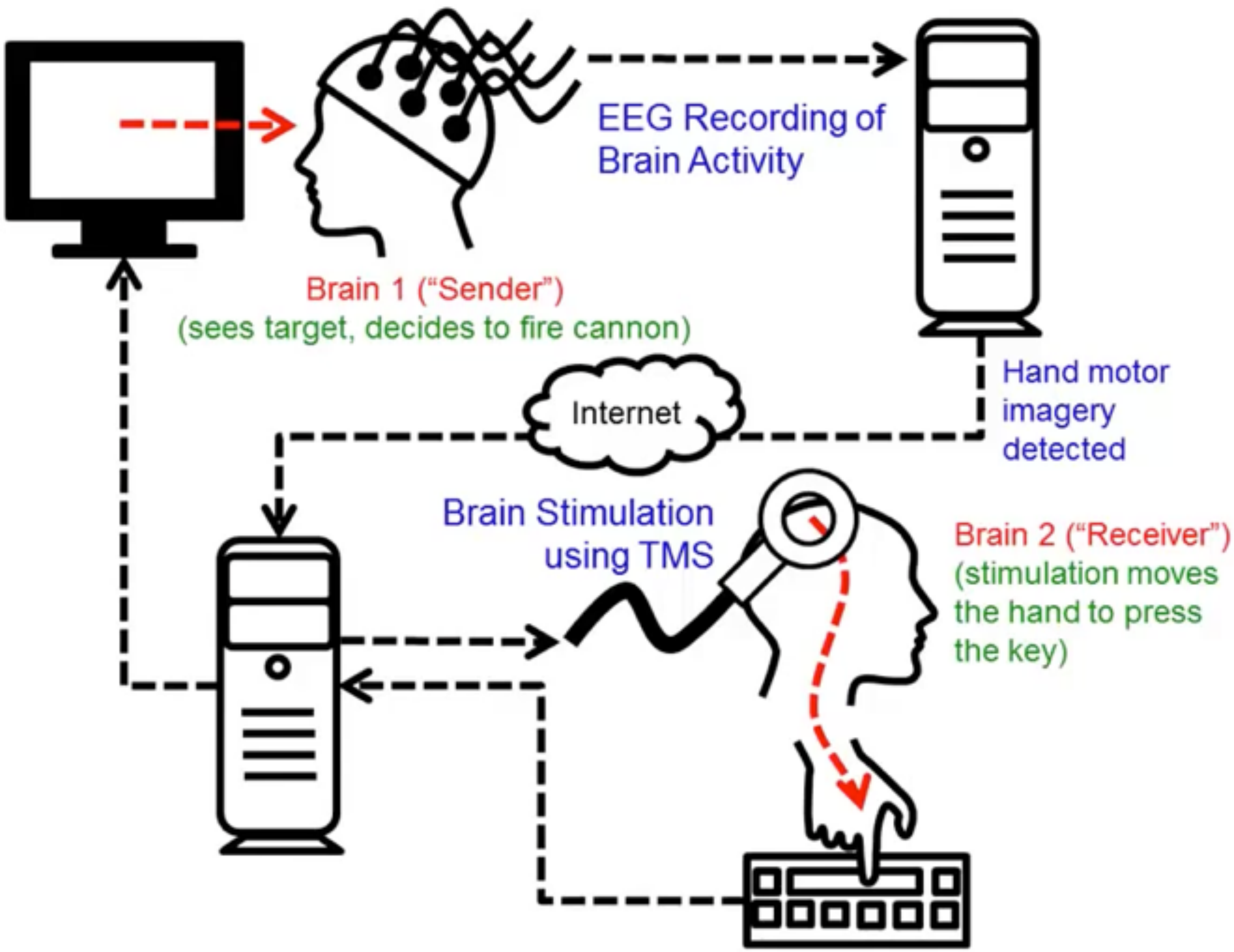
**cannot stop thinking!** midas touch problem

(king turns everything into gold,
even his daughter)

where is this going next?

**<30s brainstorming>**

# brain-to-brain stimulation::




**2013:** Rajesh Rao sent a brain signal to Andrea Stocco


**2013:** Rajesh Rao sent a brain signal to Andrea Stocco

**TMS (transcranial magnetic stimulation) ::**

uses a coil which induces **small currents** into the brain via electromagnetic induction

# TALK:

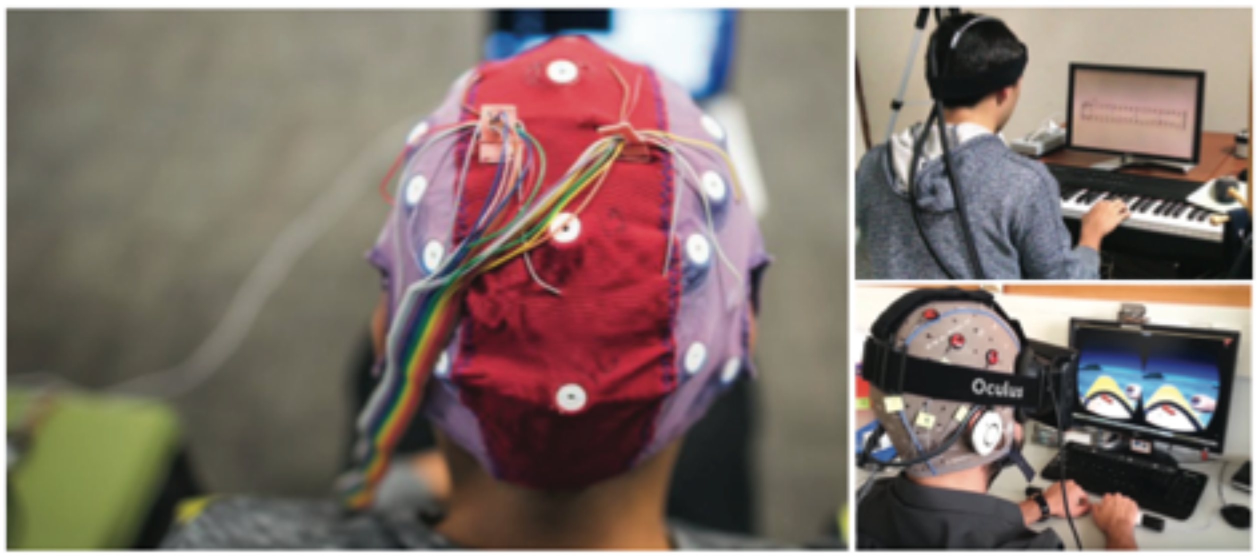
CSAIL HCI Seminar Series 2017

## Implicit User Interfaces

Robert J.K. Jacob, Tufts University

Sep 26, 2017 | 2pm - 3pm | Kiva (32-G449)

Host: Stefanie Mueller, MIT CSAIL




## Abstract


Implicit user interfaces passively obtain information from their users, typically in addition to mouse, keyboard, or other explicit inputs. They fit into the emerging trends of physiological computing and affective computing. Our work focuses on using brain input for this purpose, measured through functional near-infrared spectroscopy, as a way of increasing the narrow communicationbandwidth between human and computer. In this talk, I will discuss our work on brain-computer interfaces and the more general area of implicit interaction. I will also discuss our concept of Reality-Based Interaction as a unifying framework that ties together a large subset of emerging new, non-WIMP user interfaces. I will briefly discuss some past work in my research group on a variety of next generation interfaces such as tangible interfaces and implicit eye movement-based interaction techniques.


## Bio

Robert Jacob is a Professor of Computer Science at Tufts University, where his research interests are new interaction modes and techniques and user interface software; his current work focuses on implicit brain-computer interfaces. He has been a Visiting Professor at the University College London Interaction Centre, Universite Paris-Sud, and the MIT Media Laboratory. He received his Ph.D. from Johns Hopkins University, and he is a member of the editorial board for the journal Human-Computer Interaction and a founding member for ACM Transactions on Computer-Human Interaction.

more information:
hci.mit.edu/hci-seminar.html

come to the HCI seminar some time!

http://hci.csail.mit.edu/hci-seminar.html

# #2

## muscle computer interfaces


the creators project

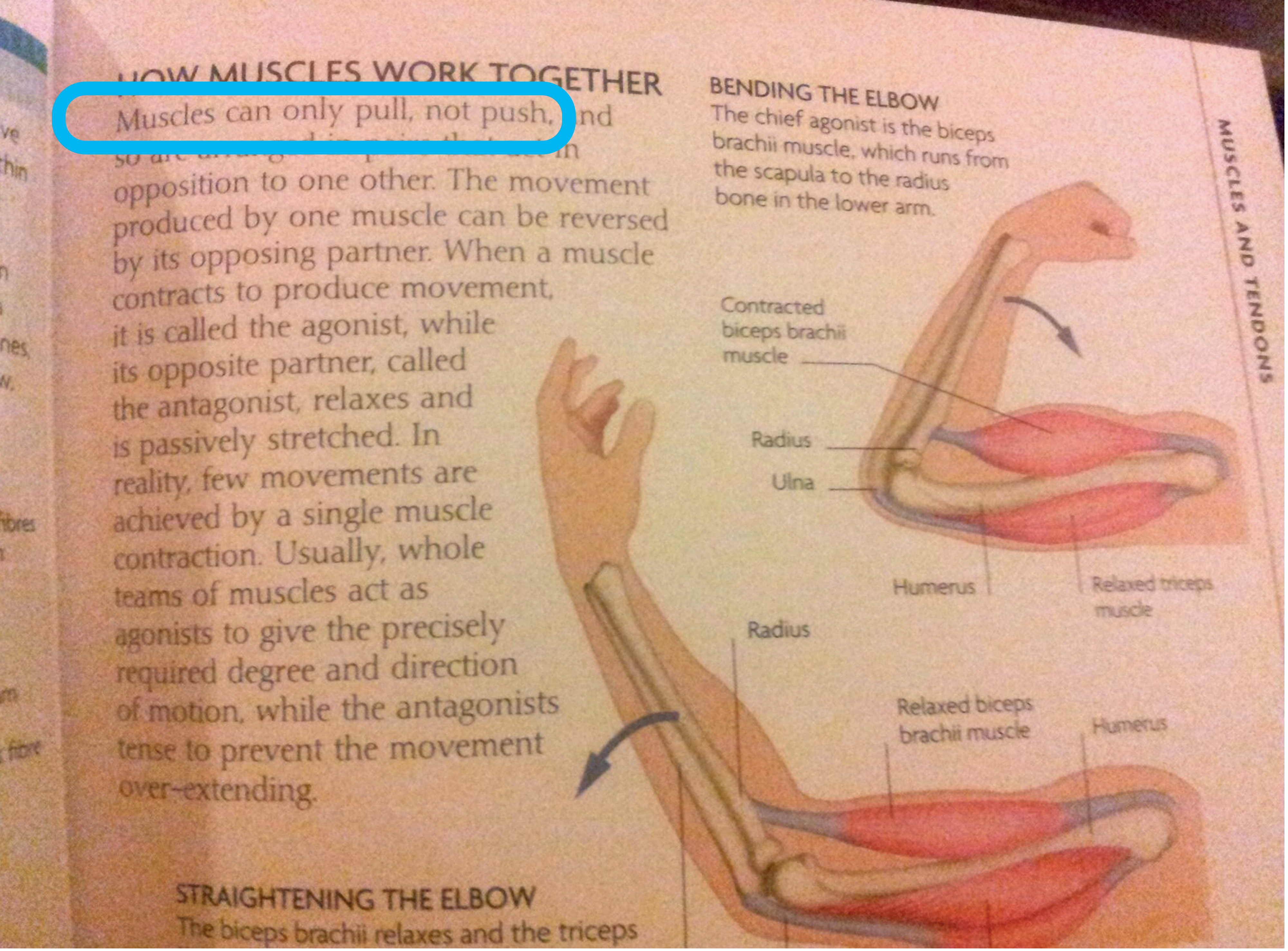
where could this lead?

what would you do with the ability to move sb else's muscles?

**<30s brainstorming>**

# electro-muscle stimulation (EMS):

- originated in rehabilitation medicine in the 60's
- current applied to muscle activates 'muscle neurons'



## HOW MUSCLES WORK TOGETHER

Muscles can only pull, not push, and so are arranged in pairs that act in opposition to one other. The movement produced by one muscle can be reversed by its opposing partner. When a muscle contracts to produce movement, it is called the agonist, while its opposite partner, called the antagonist, relaxes and is passively stretched. In reality, few movements are achieved by a single muscle contraction. Usually, whole teams of muscles act as agonists to give the precisely required degree and direction of motion, while the antagonists tense to prevent the movement over-extending.

**BENDING THE ELBOW**

The chief agonist is the biceps brachii muscle, which runs from the scapula to the radius bone in the lower arm.

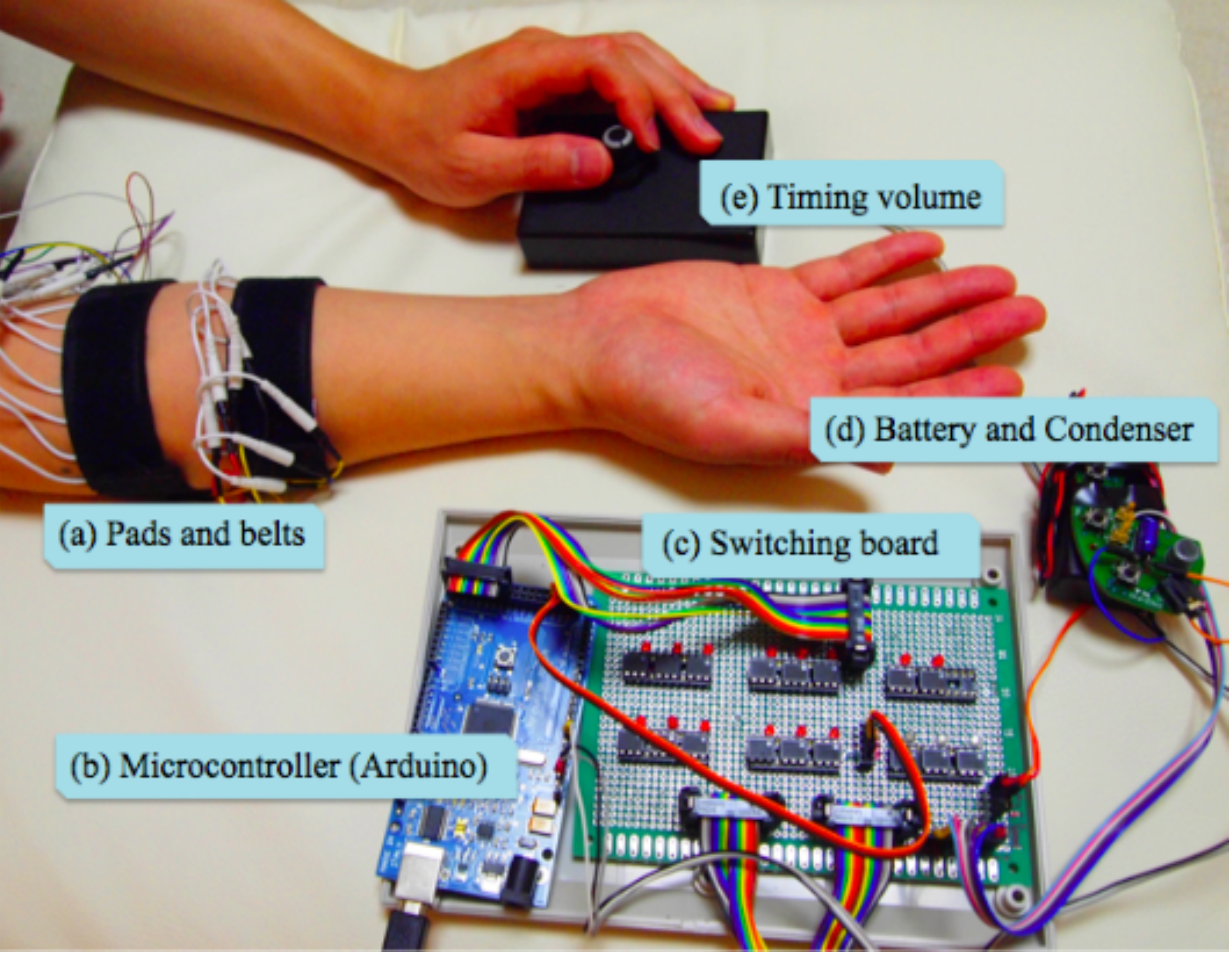


**STRAIGHTENING THE ELBOW**

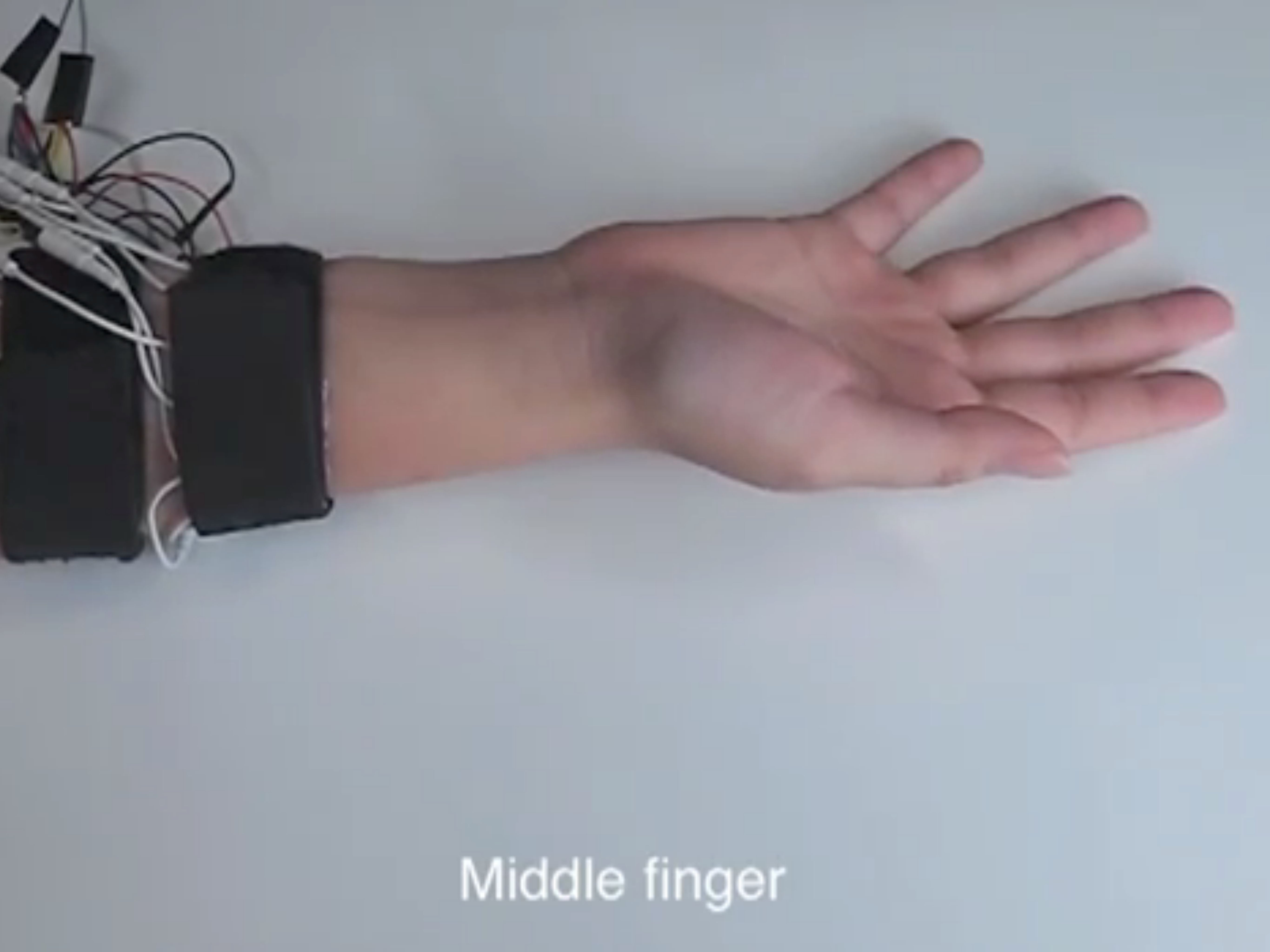
The biceps brachii relaxes and the triceps

# muscle contraction ::

muscles can **only contract,** i.e. pull not push




**2011:** Jun Rekimoto: Posessed Hand


Middle finger

# PossessedHand: Techniques for Controlling Human Hands using Electrical Muscles Stimuli

**Emi Tamaki**
Graduate school of Interdisciplinary Information Studies, The University of Tokyo.
hoimei@acm.org

**Takashi Miyaki**
Interfaculty Initiative in Information Studies, The University of Tokyo.
miyaki@acm.org

**Jun Rekimoto**
Interfaculty Initiative in Information Studies, The University of Tokyo.
Sony Computer Science Laboratories, Inc.
rekimoto@acm.org

## ABSTRACT

If a device can control human hands, the device can be useful for HCI and tangible application's output. To aid the controlling of finger movement, we present PossessedHand, a device with a forearm belt that can inform when and which fingers should be moved. PossessedHand controls the user's fingers by applying electrical stimulus to the muscles around the forearm. Each muscle is stimulated via 28 electrode pads. Muscles at different depths in the forearm can be selected for simulation by varying the stimulation level. PossessedHand can automatically calibrate the system for individuals. The automatic calibration system estimates relations between each electrode pad, stimulation level and muscle movement. Experiments show that PossessedHand can control the motion of 16 joints in the hand. Further, we also discuss an application based on this device to aid in playing a musical instrument.

## Author Keywords

EMS, FES, Electric Stimulation, Hand Gesture, Musical Performance

## ACM Classification Keywords

H.5 Information interfaces and presentation: [HCI]

## General Terms

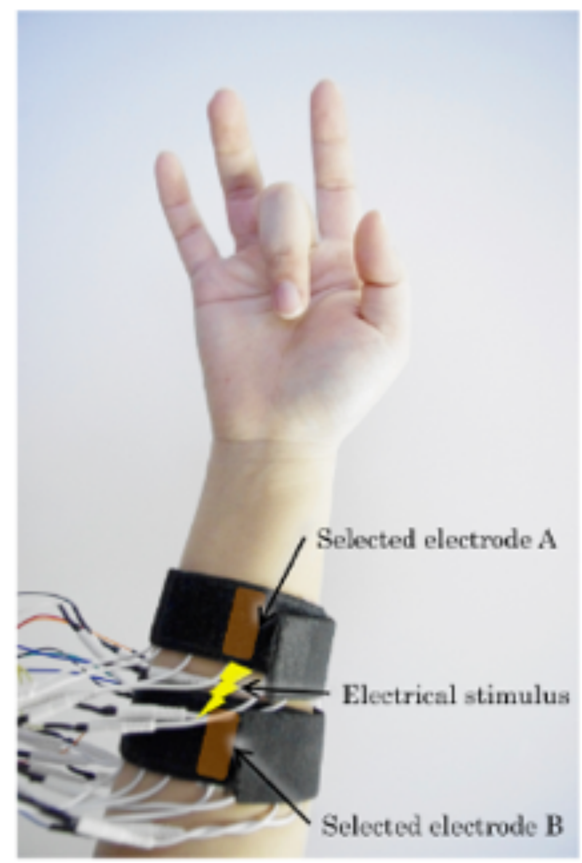
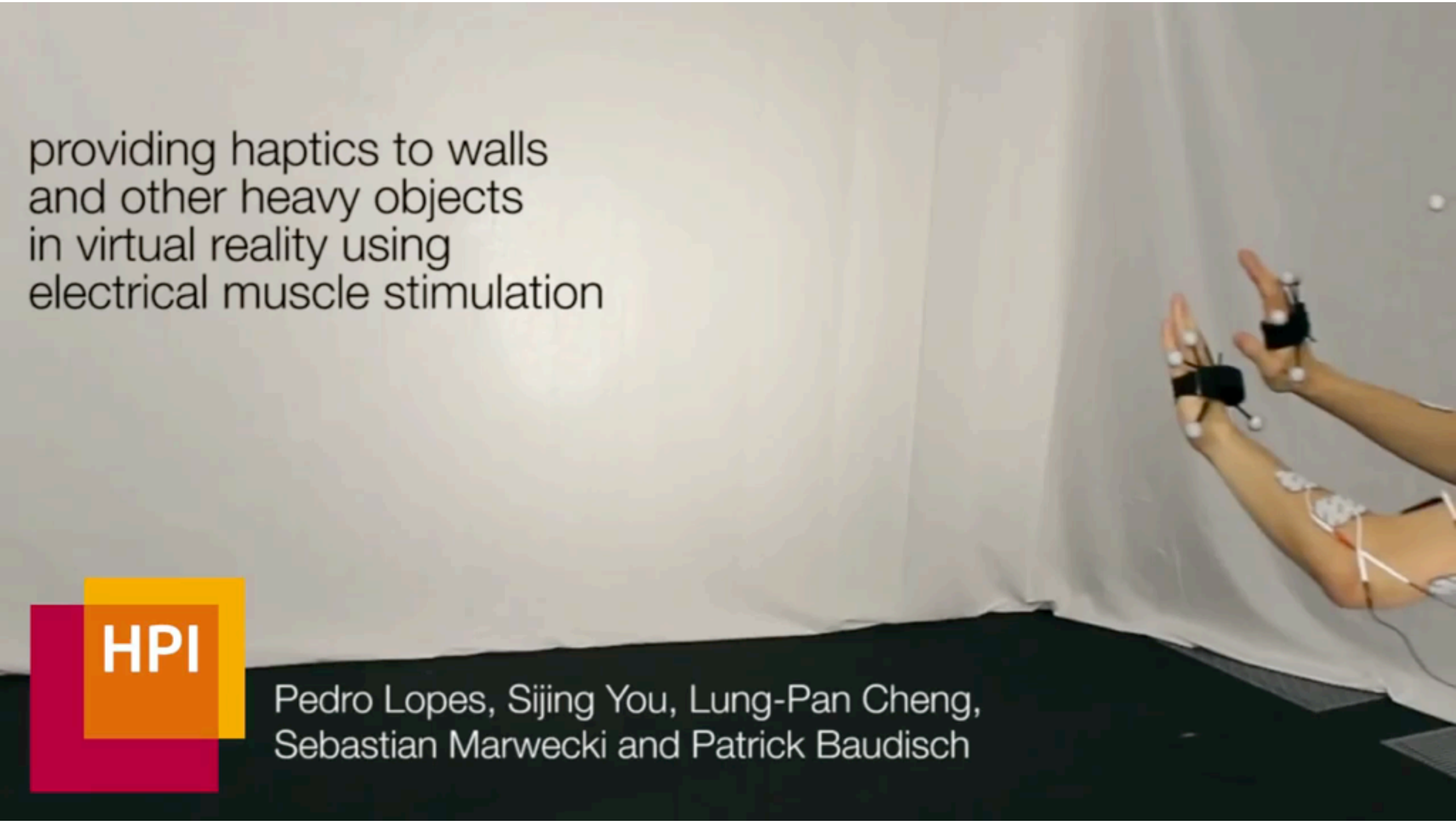



**Figure 1. Our concept. PossessedHand controls user's finger.**

a device can control human hands, the device would lead the next generation of HCI and tangle applications.

In this paper, we introduce PossessedHand, a device with a


providing haptics to walls
and other heavy objects
in virtual reality using
electrical muscle stimulation
HPI
Pedro Lopes, Sijing You, Lung-Pan Cheng,
Sebastian Marwecki and Patrick Baudisch

# Providing Haptics to Walls & Heavy Objects in Virtual Reality by Means of Electrical Muscle Stimulation

**Pedro Lopes, Sijing You, Lung-Pan Cheng, Sebastian Marwecki, and Patrick Baudisch**
Hasso Plattner Institute
Potsdam, Germany
{firstname.lastname}@hpi.de

## ABSTRACT
We explore how to add haptics to walls and other heavy objects in virtual reality. When a user tries to push such an object, our system actuates the user's shoulder, arm, and wrist muscles by means of electrical muscle stimulation, creating a counter force that pulls the user's arm backwards. Our device accomplishes this in a wearable form factor.

In our first user study, participants wearing a head-mounted display interacted with objects provided with different types of EMS effects. The *repulsion* design (visualized as an electrical field) and the *soft* design (visualized as a magnetic field) received high scores on "prevented me from passing through" as well as "realistic."

In a second study, we demonstrate the effectiveness of our approach by letting participants explore a virtual world in which all objects provide haptic EMS effects, including walls, gates, sliders, boxes, and projectiles.

### Author Keywords
Muscle interfaces; virtual reality; EMS; force feedback.

### ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

## INTRODUCTION
Recent virtual reality systems allow users to walk freely in the virtual world (aka *real walking* [36]). As the next step towards realism and immersion, many researchers argue that these systems should also support the haptic sense in

Unfortunately, adding haptics to *heavy* objects, such as furniture or walls, has proven substantially more challenging. Even if one simulates the tactile aspects of such objects, the illusion fails as soon as users try to *push* through the object, as their proprioceptive system informs them about the lack of resistance [28].

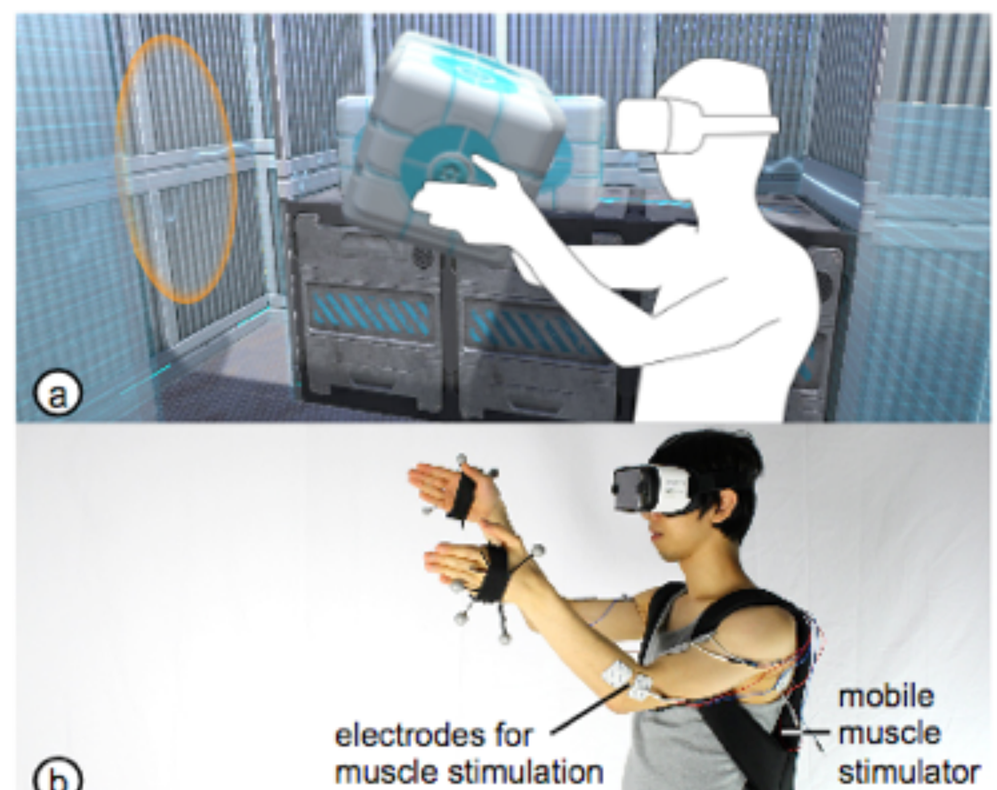



**Figure 1: (a) As this user lifts a virtual cube, our system lets the user feel the weight and resistance of the cube. (b) Our system implements this by actuating the user's *opposing* muscles using electrical muscle stimulation.**


impacto
Simulating Physical Impact by Combining Tactile with Electrical Muscle Stimulation
Oculus
Pedro Lopes, Alexandra Ion, and Patrick Baudisch
HPI Hasso Plattner Institut

# Impacto: Simulating Physical Impact by Combining Tactile Stimulation with Electrical Muscle Stimulation

**Pedro Lopes, Alexandra Ion, and Patrick Baudisch**
Hasso Plattner Institute, Potsdam, Germany
{firstname.lastname}@hpi.de

## ABSTRACT

We present impacto, a device designed to render the haptic sensation of hitting and being hit in virtual reality. The key idea that allows the small and light impacto device to simulate a strong hit is that it decomposes the stimulus: it renders the tactile aspect of being hit by tapping the skin using a solenoid; it adds impulse to the hit by thrusting the user's arm backwards using electrical muscle stimulation. The device is self-contained, wireless, and small enough for wearable use, and thus leaves the user unencumbered and able to walk around freely in a virtual environment. The device is of generic shape, allowing it to also be worn on legs so as to enhance the experience of kicking, or merged into props, such as a baseball bat. We demonstrate how to assemble multiple impacto units into a simple haptic suit. Participants of our study rated impacts simulated using impacto's combination of a solenoid hit and electrical muscle stimulation as more realistic than either technique in isolation.

**ACM Classification**: H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

**Keywords:** haptics; impact, virtual reality; mobile; wearable; electrical muscle stimulation; solenoid; force feedback

**General terms:** Design, Human factors.

## INTRODUCTION

The objective of virtual reality systems is to provide an immersive and realistic experience [28]. While research in virtual reality has traditionally focused on the visual and

Simulating impact is challenging though. Creating the impulse that is transferred when hit by a kilogram-scale object, such as a boxer's fist, requires getting a kilogram-scale object into motion and colliding it with the user. This requires a very heavy device. In addition, building up an impulse requires an anchor to push against (Newton's Third Law), typically resulting in a tethered device, e.g., SPIDAR [22]. Both clash with the notion that today's virtual reality hardware is already wearable and wireless [9].

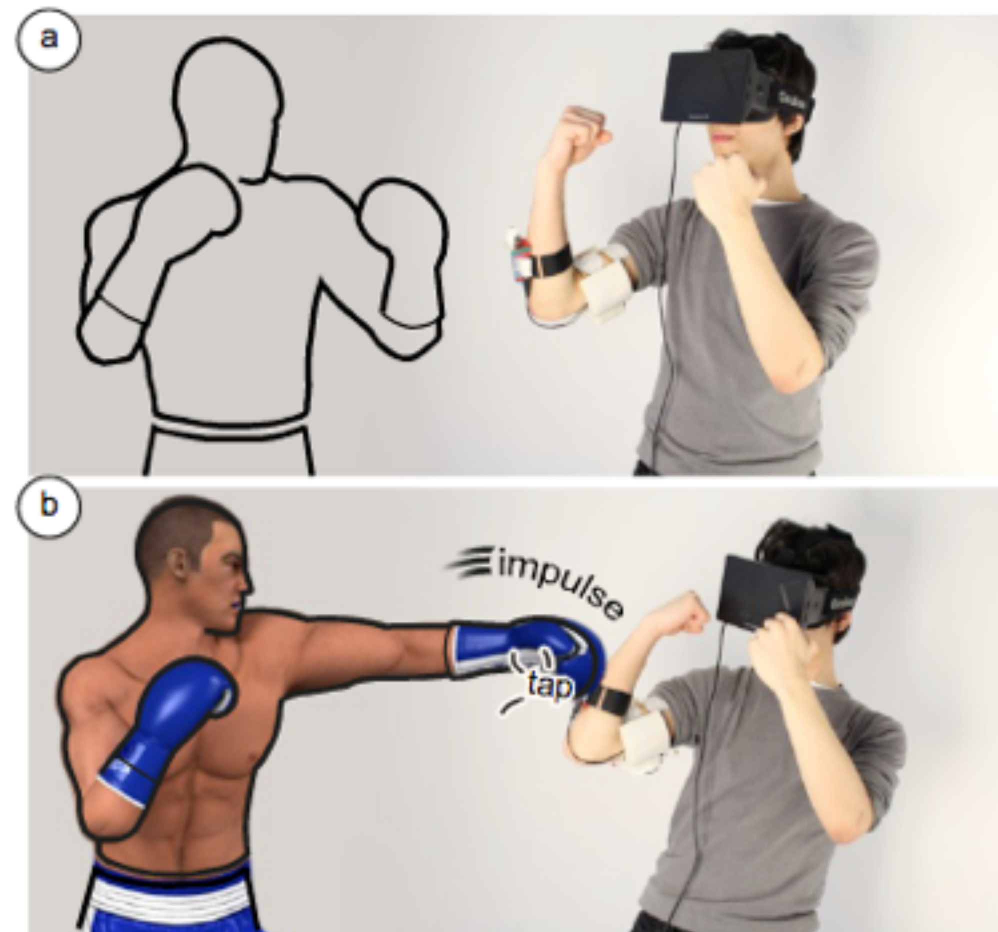
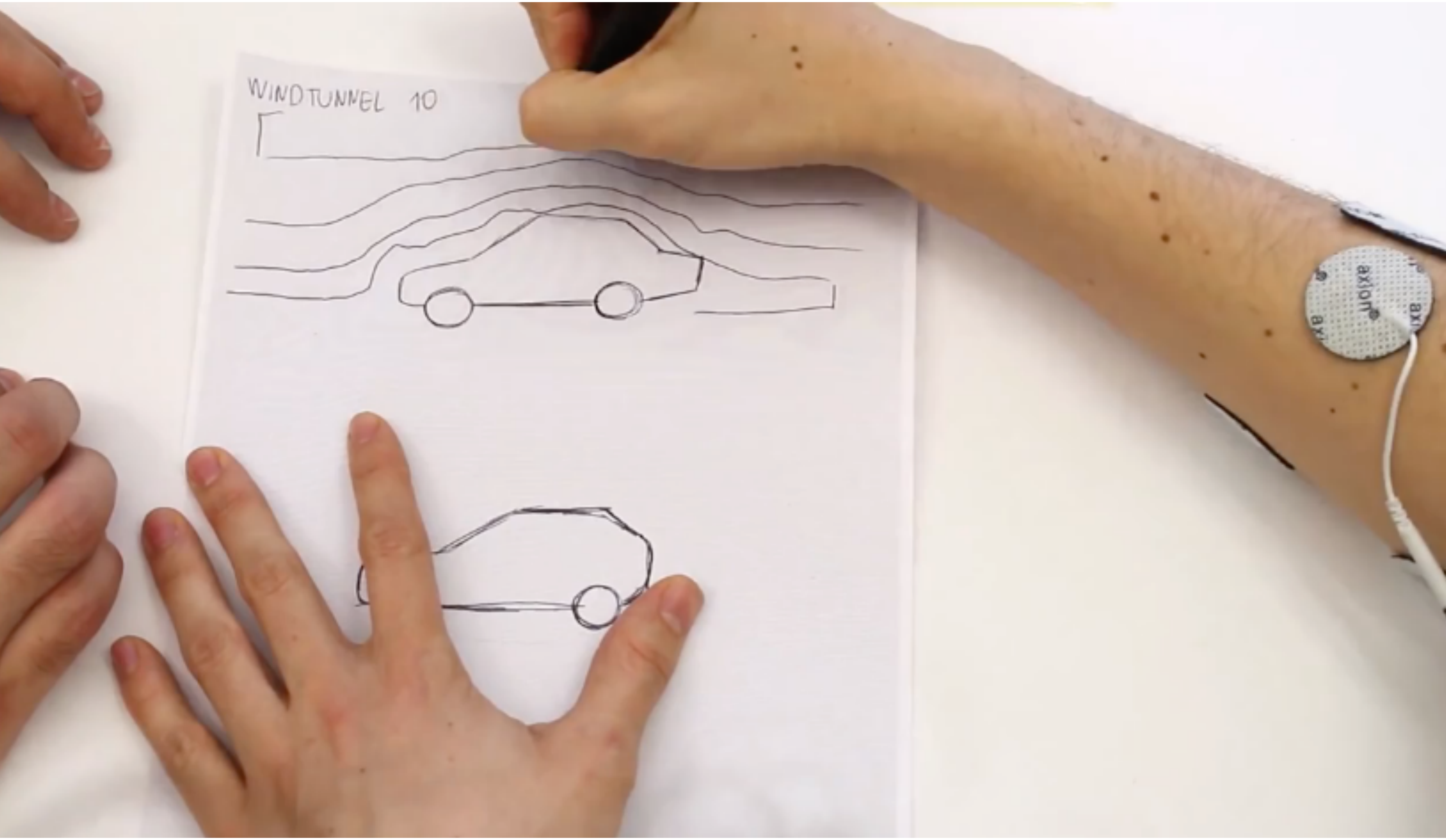



**Figure 1: Impacto is designed to render the haptic sensation of**




**2011:** Pedro Lopes: Muscle Force Feedback

# Muscle-plotter: an Interactive System based on Electrical Muscle Stimulation that Produces Spatial Output

**Pedro Lopes[1], Doğa Yüksel[1], François Guimbretière[1,2], and Patrick Baudisch[1]**

[1] Hasso Plattner Institute
Potsdam, Germany
{firstname.lastname}@hpi.de

[2] Cornell University, Information Science
Ithaca, NY 14850, USA
francois@cs.cornell.edu

## ABSTRACT

We explore how to create interactive systems based on electrical muscle stimulation that offer expressive output. We present muscle-plotter, a system that provides users with input *and output* access to a computer system while on the go. Using pen-on-paper interaction, muscle-plotter allows users to engage in cognitively demanding activities, such as writing math. Users write formulas using a pen and the system responds by making the users' hand draw charts and widgets. While Anoto technology in the pen tracks users' input, muscle-plotter uses electrical muscle stimulation (EMS) to steer the user's wrist so as to plot charts, fit lines through data points, find data points of interest, or fill in forms. We demonstrate the system at the example of six simple applications, including a wind tunnel simulator.

The key idea behind muscle-plotter is to make the user's hand sweep an area on which muscle-plotter renders curves, i.e., series of values, and to *persist* this EMS output by means of the pen. This allows the system to build up a larger whole. Still, the use of EMS allows muscle-plotter to achieve a compact and mobile form factor. In our user study, muscle-plotter made participants draw random plots with an accuracy of ±4.07 mm and preserved the frequency of functions to be drawn up to 0.3 cycles per cm.

**Keywords:** electrical muscle stimulation; spatial; haptics;

**ACM Classification:** H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

## INTRODUCTION

Interactive systems based on electrical muscle stimulation

The main strength of EMS is that the resulting systems miniaturize well, thus lend themselves well to mobile use (mobile gaming [16]) or wearable use (*pedestrian cruise control* [23]). A second key strength is their ability to implement input/output interactions that use the same modality (i.e., *symmetric* interaction [25]) by using the same gesture language for input and output [17].

Unfortunately, the price for these benefits is that the interactive EMS systems presented so far lack expressiveness. Existing interactive EMS systems output a single 1D output variable, such as screen tilt [16] *or* wrist tilt [17] *or* one of *n* behaviors [18]. Since subsequent output overwrites earlier output, users never see more than a single value.

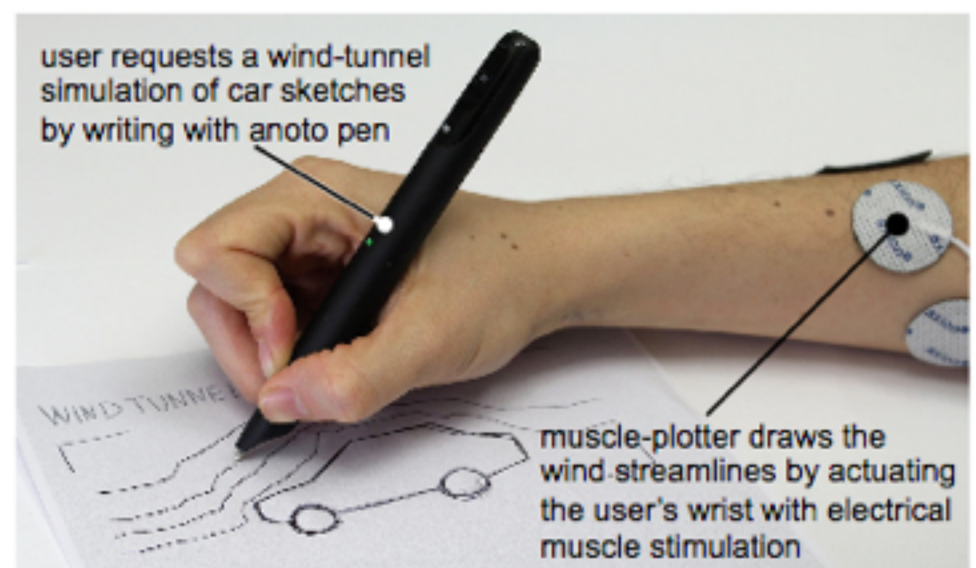
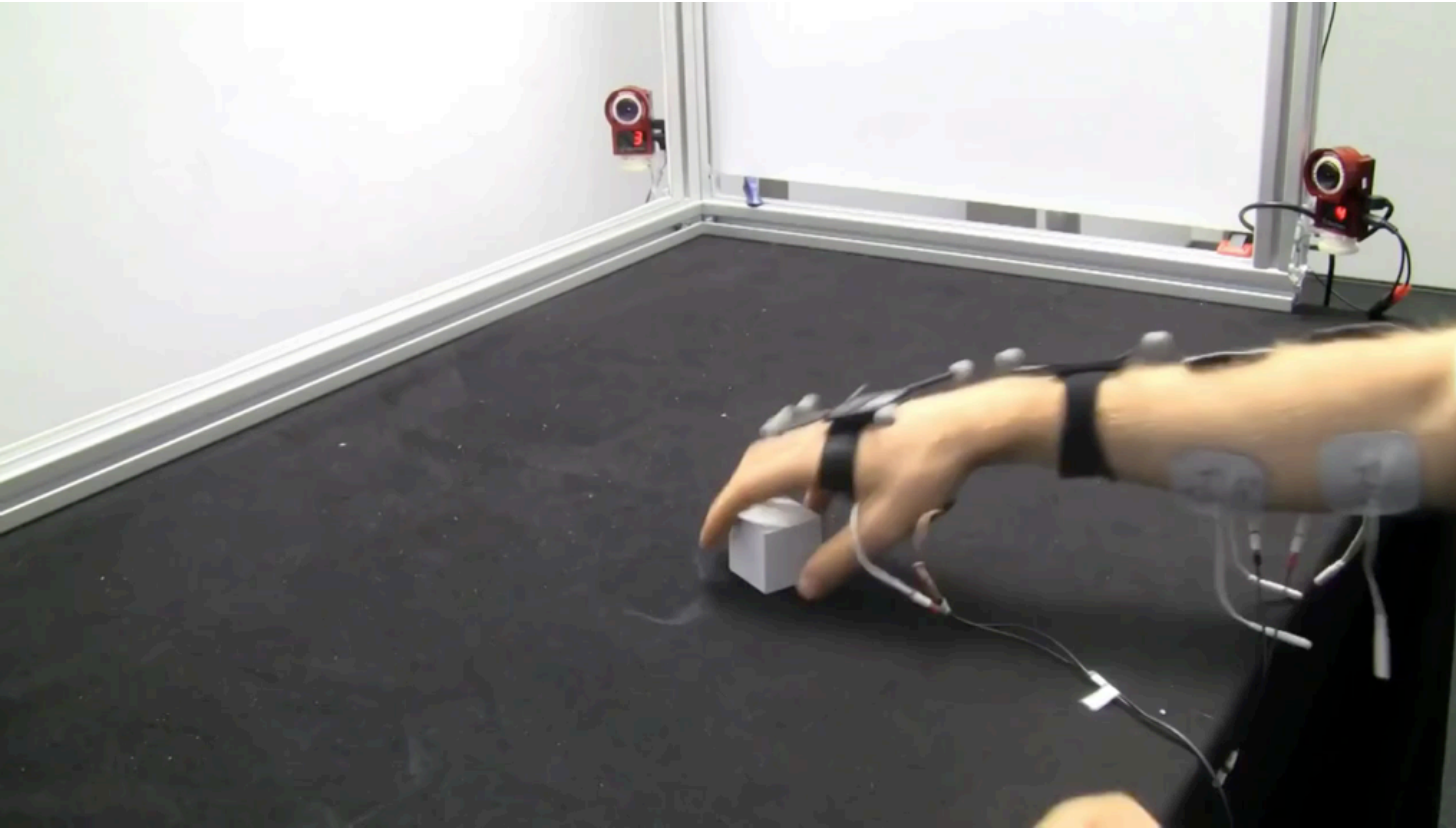



**Figure 1: An interactive wind tunnel simulation with pen input and output—based on EMS. The user jotted down the word "windtunnel", set down the pen left of the car, and started to drag it towards the car sketch. In response, muscle-plotter computed this particular streamline in the context of**



# Affordance++: allowing objects to communicate dynamic use

**Pedro Lopes, Patrik Jonell, and Patrick Baudisch**
Hasso Plattner Institute, Potsdam, Germany
{firstname.lastname}@hpi.de

## ABSTRACT
We propose extending the affordance of objects by allowing them to communicate *dynamic* use, such as (1) motion (e.g., spray can shakes when touched), (2) multi-step processes (e.g., spray can sprays only after shaking), and (3) behaviors that change over time (e.g., empty spray can does not allow spraying anymore). Rather than enhancing objects directly, however, we implement this concept by enhancing the user. We call this *affordance++*. By stimulating the user's arms using electrical muscle stimulation, our prototype allows objects not only to make the user actuate them, but also perform required movements while merely approaching the object, such as *not* to touch objects that do not "want" to be touched. In our user study, affordance++ helped participants to successfully operate devices of poor natural affordance, such as a multi-functional slicer tool or a magnetic nail sweeper, and to stay away from cups filled with hot liquids.

**Keywords**: electrical muscle stimulation; affordance;

**ACM Classification**: H5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles.

## INTRODUCTION
Affordance is a key concept in usability. When well-designed objects "suggest how to be used" [7], they avoid the necessity for training and enable walk-up use. Physical objects, for example, use their visual and tactile cues to suggest the possible range of usages to the user [7].

Unfortunately, physical objects are limited in that they can-be used for spraying anymore (and instead should now be thrown away).

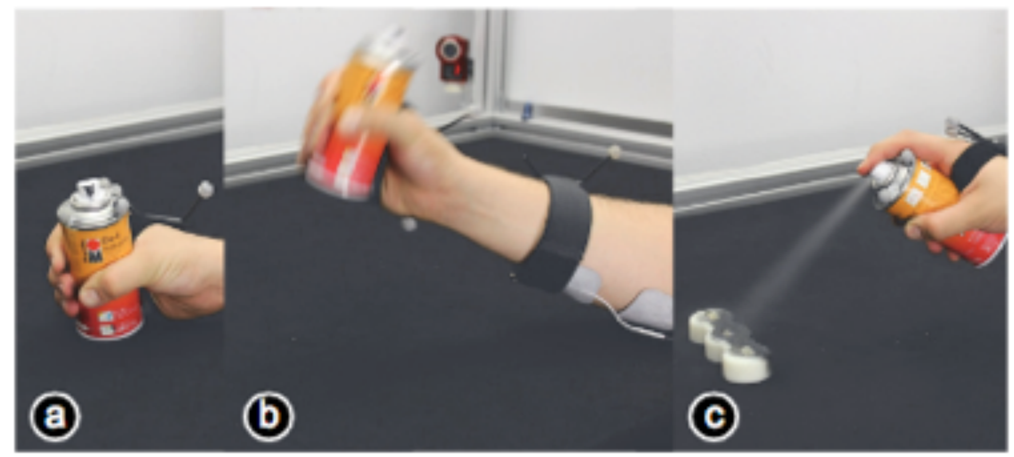



**Figure 1: Affordance++ expands the affordance of an object beyond its visual attributes. (a) This spray can needs to be shaken before use. (b) Affordance++ allows the spray can to make the user shake it before use. Our prototype implements this by electrically stimulating the user's muscles. (c) Now the spray can is "willing" to be used.**

As pointed out by Djajadiningrat et al., the underlying limitation of this type of physical object is that they cannot depict *time* [3]. The spray can is inanimate. Motion, multi-step processes, and behaviors that change over time, however, are phenomena in time.

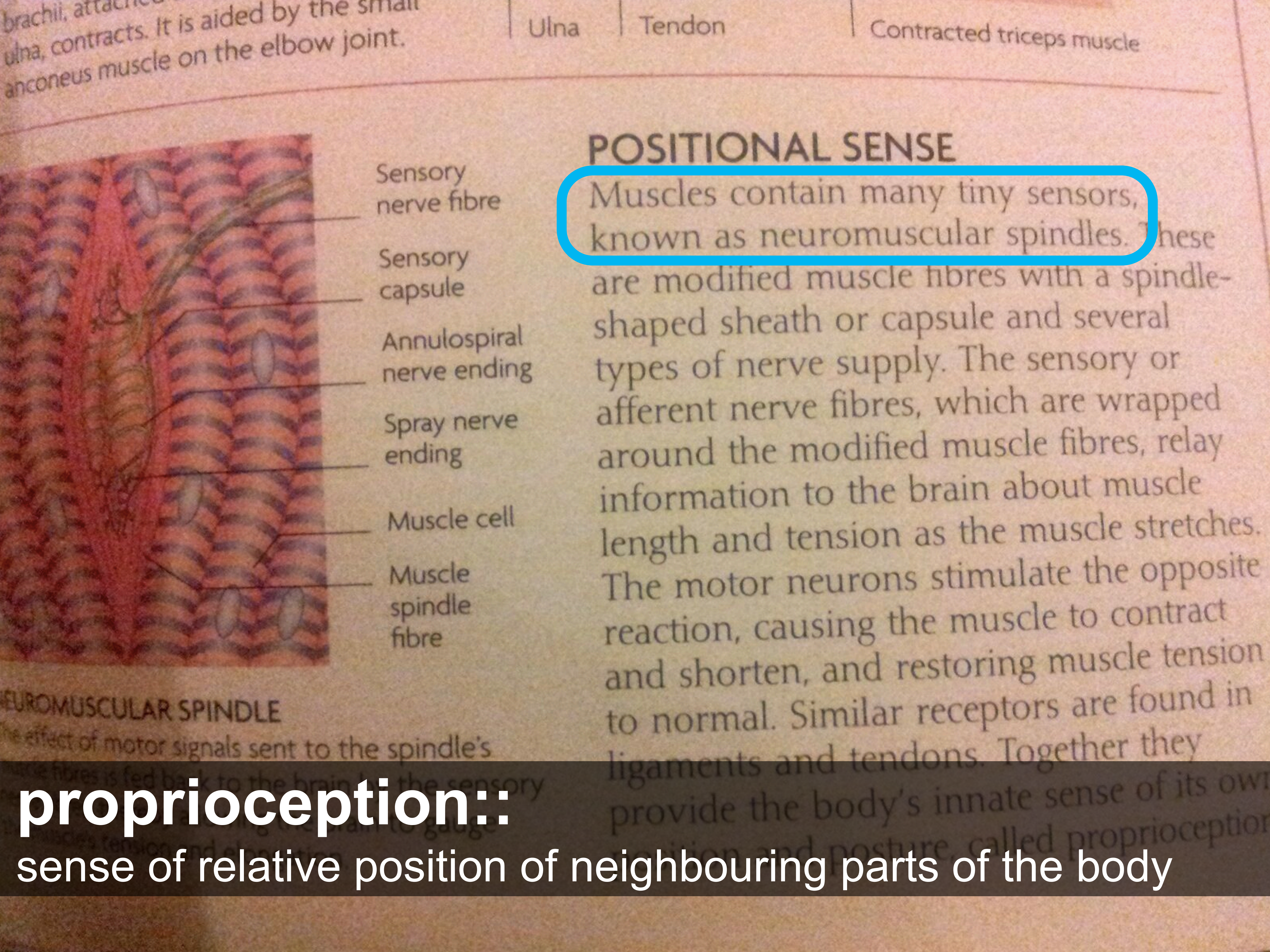
One way of addressing the issue is to provide objects with the ability to display instructions, e.g., using a spatial augmented reality display [20]. To offer a more "direct" way for objects to communicate their use, researchers have embedded sensors and actuators into objects, allowing them to be animated [21,25]. This approach works, unfortunately, at the

# sensing muscle contraction

can I make a pose with my hand with my **eyes closed?**

so how do I actually
**know when to stop** pulling my muscles?

**<30s brainstorming>**


ulna, contracts. It is aided by the small
anconeus muscle on the elbow joint.
Ulna
Tendon
Contracted triceps muscle
POSITIONAL SENSE
Muscles contain many tiny sensors, known as neuromuscular spindles. These are modified muscle fibres with a spindle-shaped sheath or capsule and several types of nerve supply. The sensory or afferent nerve fibres, which are wrapped around the modified muscle fibres, relay information to the brain about muscle length and tension as the muscle stretches. The motor neurons stimulate the opposite reaction, causing the muscle to contract and shorten, and restoring muscle tension to normal. Similar receptors are found in ligaments and tendons. Together they provide the body's innate sense of its own position and posture, called proprioception
Sensory nerve fibre
Sensory capsule
Annulospiral nerve ending
Spray nerve ending
Muscle cell
Muscle spindle fibre
NEUROMUSCULAR SPINDLE
The effect of motor signals sent to the spindle's
proprioception::
sense of relative position of neighbouring parts of the body

this is how a human senses muscle activity!

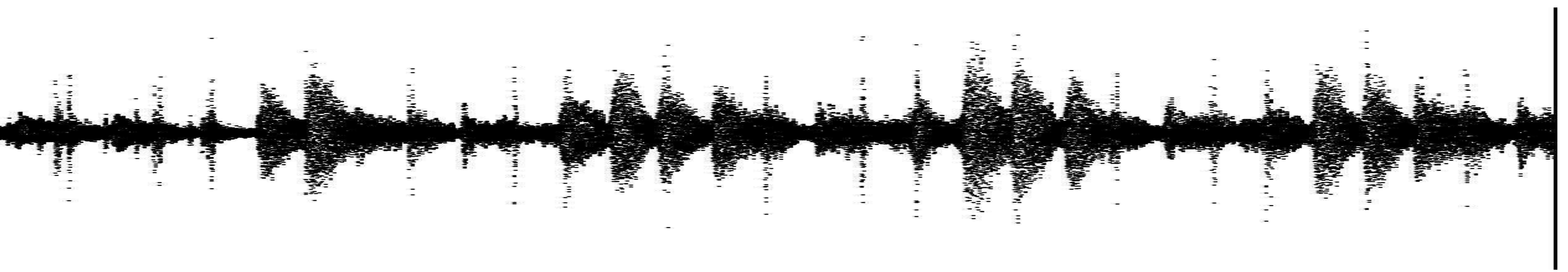
but how does a **computer** do it?

# sensing muscle:

- **MMG** (mechanomyography)
- **EMG** (electromyography)
- optical, tip force sensor, classical FSR, piezo

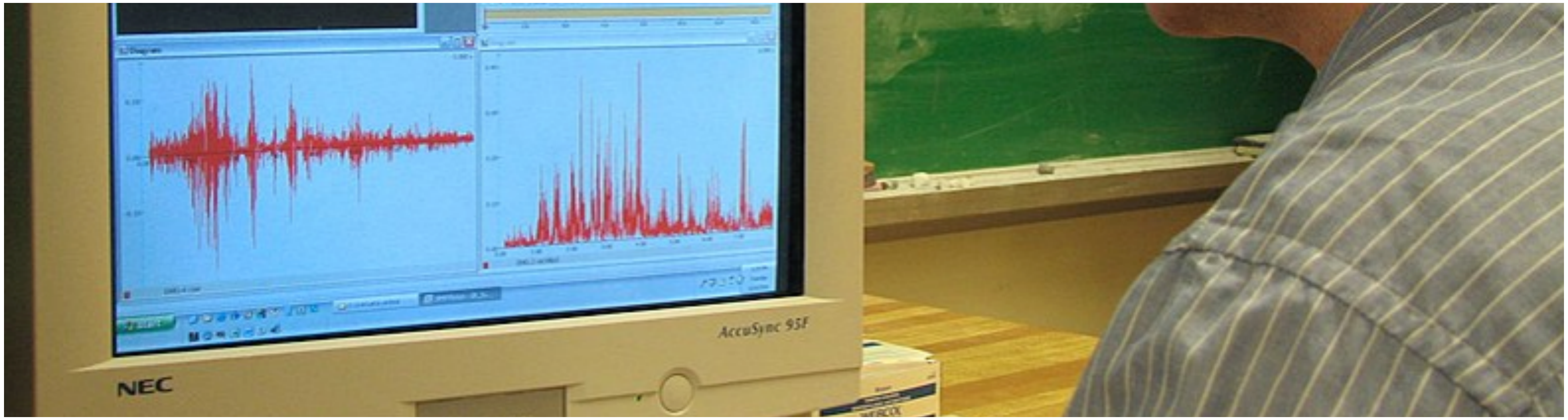
# MMG (mechano-myogram)::

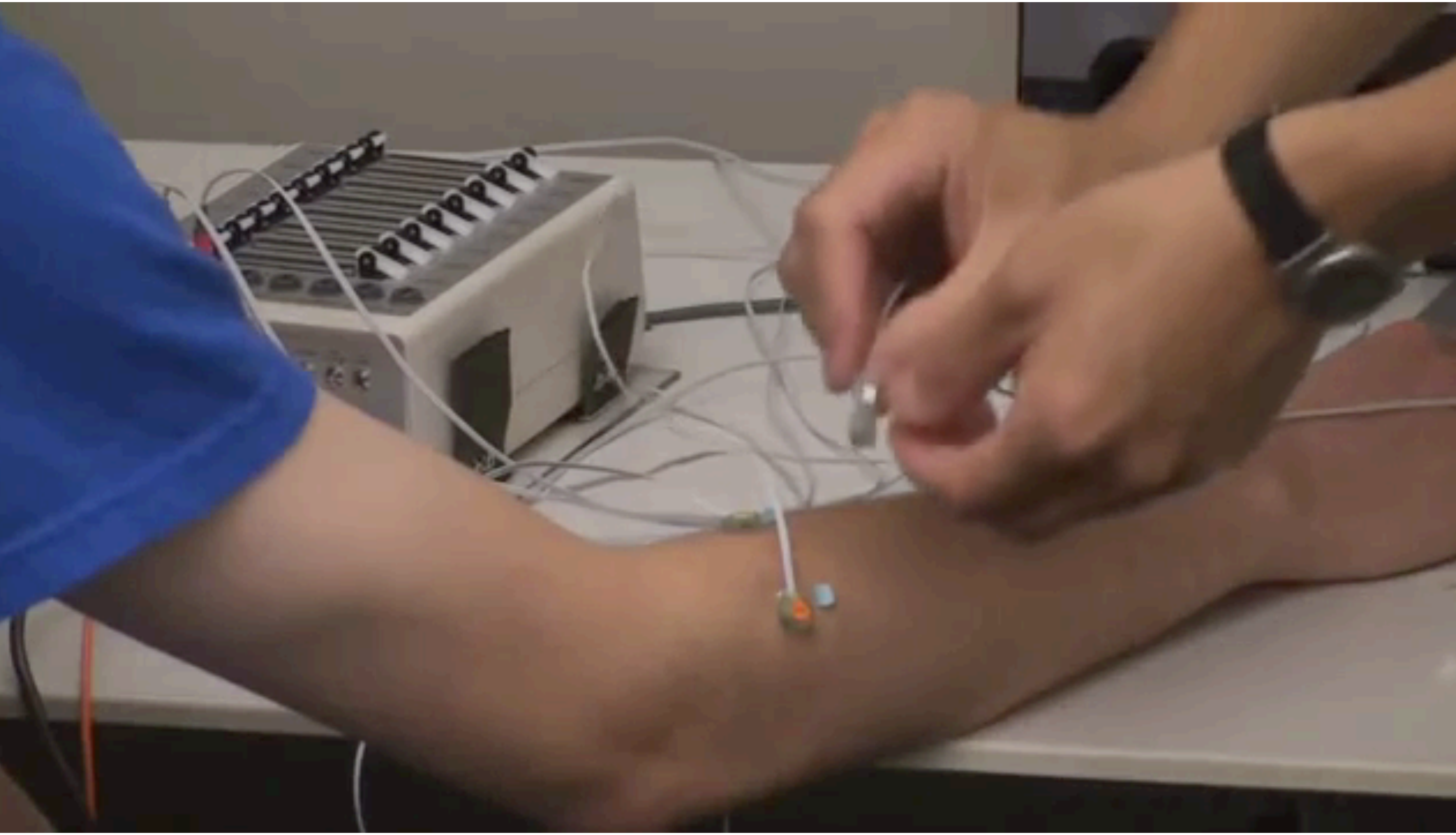
- a vibration that can be observed when a muscle contracts
- use a microphone or accelerometer placed on the skin



# EMG (electro-myogram)::

- nerves control muscles in the body using electric signals
- electric signal makes muscle fibers contract
- measure electric potential of muscle at rest vs. used






Potential Applications

# Enabling Always-Available Input with Muscle-Computer Interfaces

*T. Scott Saponas[1], Desney S. Tan[2], Dan Morris[2], Ravin Balakrishnan[4], Jim Turner[3], James A. Landay[1]*

[1]Compuer Science and Engineering
DUB Group
University of Washington
{ssaponas, landay}@cs.washington.edu

[2]Microsoft Research
{desney, dan}@microsoft.com

[3]Microsoft Corporation
jturner@microsoft.com

[4]Department of
Computer Science
University of Toronto
ravin@dgp.toronto.edu

**ABSTRACT**

Previous work has demonstrated the viability of applying offline analysis to interpret forearm electromyography (EMG) and classify finger gestures on a physical surface. We extend those results to bring us closer to using muscle-computer interfaces for always-available input in real-world applications. We leverage existing taxonomies of natural human grips to develop a gesture set covering interaction in free space even when hands are busy with other objects. We present a system that classifies these gestures in real-time and we introduce a bi-manual paradigm that enables use in interactive systems. We report experimental results demonstrating four-finger classification accuracies averaging 79% for pinching, 85% while holding a travel mug, and 88% when carrying a weighted bag. We further show generalizability across different arm postures and explore the tradeoffs of providing real-time visual feedback.

**ACM Classification:** H.1.2 [User/Machine Systems]; H.5.2 [User Interfaces]: Input devices and strategies; B.4.2 [Input/Output Devices]: Channels and controllers

**General terms**: Design, Human Factors

**Keywords:** Electromyography (EMG), Muscle-Computer Interface, input, interaction.

## INTRODUCTION

Previous work has explored hands-free and implement-free input techniques based on a variety of sensing modalities. For example, computer vision enables machines to recognize faces, track movement and gestures, and reconstruct 3D scenes [24]. Similarly, speech recognition allows for hands-free interaction, enabling a variety of speech-based desktop and mobile applications [8, 11]. However, these technologies have several inherent limitations. First, they require observable interactions that can be inconvenient or socially awkward. Second, they are relatively sensitive to environmental factors such as light and noise. Third, in the case of computer vision, sensors that visually sense the environment are often susceptible to occlusion.

We assert that computer input systems can leverage the full bandwidth of finger and hand gestures without requiring the user to manipulate a physical transducer. In this paper, we show how forearm electromyography (EMG) can be used to detect and decode human muscular movement in real time, thus enabling interactive finger gesture interaction. We envision that such sensing can eventually be achieved with an unobtrusive wireless forearm EMG band (see Figure 1).

Previous work exploring muscle-sensing for input has primarily focused either on using a single large muscle (rather than the fingers) [2, 3, 4, 22, 25], which does not provide the breadth of input signals required for computer input,

# #3

## other body-signals as interface

any idea how this works>

**<30s brainstorming>**

## galvanic vestibular stimulation:

sense of balance: liquid level in ear
electrodes stimulate liquid in ear

Maeda et al., Shaking the world: galvanic vestibular stimulation as a novel sensation interface, SIGGRAPH’05

# Shaking The World: Galvanic Vestibular Stimulation As A Novel Sensation Interface

Maeda T.[*], Ando H., Amemiya T.,
NTT Communication Science Laboratories

Nagaya N., Sugimoto M., Inami M.
The University of Electro-Communications

Figure 1: Shaking The World: Galvanic Vestibular Stimulation As A Novel Sensation Interface

## Abstract

We developed a novel sensation interface device using galvanic vestibular stimulation (GVS). GVS alters your balance. Our device can induce vection (virtual sense of acceleration) synchronized with optic flow or musical rhythms. The device can also induce lateral walking towards the anode while human walking.

**Keywords:** Communications Technology, Cognitive Psychology / Perception, Human-Computer Interfaces

## 1 Introduction

In galvanic vestibular stimulation (GVS), the vestibular system is stimulated by a weak current through an electrode placed on the mastoid behind ear. The vestibular system is sensitive to GVS intensity changes and responds by altering the magnitude of the response accordingly. GVS moves your balance toward the anode. This stimulation is has been used as the clinically functional test of vestibular. In this project, we apply GVS as a novel interface for virtual sense of acceleration. GVS can not only induce vection (virtual sense of acceleration) without an expensive mechanical motion platform. It can also make walkers deviate from the normal intended straight-line path. With our device, radio-controlled walking, automatic collision avoidance, and GPS walking navigation are possible. Moreover, the system is particularly useful for interpersonal kinematical sense sharing as an amusement by synchronizing the stimulation to the action. Movies will move you synchronized to the camera action. You and I can move each other with head action.

We developed a novel sensation interface device using GVS. It can be available to support human behavior directly. Direct walking navigation is a novel usage of GVS as a human interface. There is no feeling of enforced action. Because users are navigated very naturally and almost unconsciously, they are not distracted by the stimulation and would be aware that their behavior was an effect of the stimulation after they have done it. We designed this device also to provide a virtual sense of acceleration without an expensive mechanical platform synchronized to the flow of movies. In addition, we found the stimulation synchronized to rhythms of music provides a very fantastic experience as a novel sensation. It is useful also as a novel amusement media. Especially, by the high-frequency rhythmical stimulation of more than 1 2 Hz, you will feel as if your visual field and body shake tremblingly along with the rhythm. This experience is a novel sensation on human sensory display.

## 3 Conclusion

Until now, GVS has only been used as clinical functional test for the vestibular system. We developed a novel sensation interface using GVS. It can be available to support human behavior directly. Direct walking navigation is a novel usage of GVS as a human interface. We design this device also to work as a display for virtual sense of acceleration without expensive mechanical platform synchronized to the flow of movies. In addition, we found the stimulation synchronized to rhythms of music provides a very fantastic experience as a novel sensation. It is useful also as a novel amusement media.

# (also works with muscle-stimulation)

pedestrian cruise control [pfeiffer et al.  CHI’15]

# Cruise Control for Pedestrians: Controlling Walking Direction using Electrical Muscle Stimulation

Max Pfeiffer[1], Tim Dünte[1], Stefan Schneegass[2], Florian Alt[3], Michael Rohs[1]

[1]University of Hannover
Human-Computer Interaction
Hannover, Germany
firstname@hci.uni-hannover.de

[2]University of Stuttgart
VIS
Stuttgart, Germany
stefan.schneegass@vis.uni-stuttgart.de

[3]University of Munich
Media Informatics Group
Munich, Germany
florian.alt@ifi.lmu.de

## ABSTRACT
Pedestrian navigation systems require users to perceive, interpret, and react to navigation information. This can tax cognition as navigation information competes with information from the real world. We propose *actuated navigation*, a new kind of pedestrian navigation in which the user does not need to attend to the navigation task at all. An actuation signal is directly sent to the human motor system to influence walking direction. To achieve this goal we stimulate the sartorius muscle using electrical muscle stimulation. The rotation occurs during the swing phase of the leg and can easily be counteracted. The user therefore stays in control. We discuss the properties of actuated navigation and present a lab study on identifying basic parameters of the technique as well as an outdoor study in a park. The results show that our approach changes a user's walking direction by about 16°/m on average and that the system can successfully steer users in a park with crowded areas, distractions, obstacles, and uneven ground.

## Author Keywords
Pedestrian navigation; electrical muscle stimulation; haptic feedback; actuated navigation; wearable devices

## ACM Classification Keywords

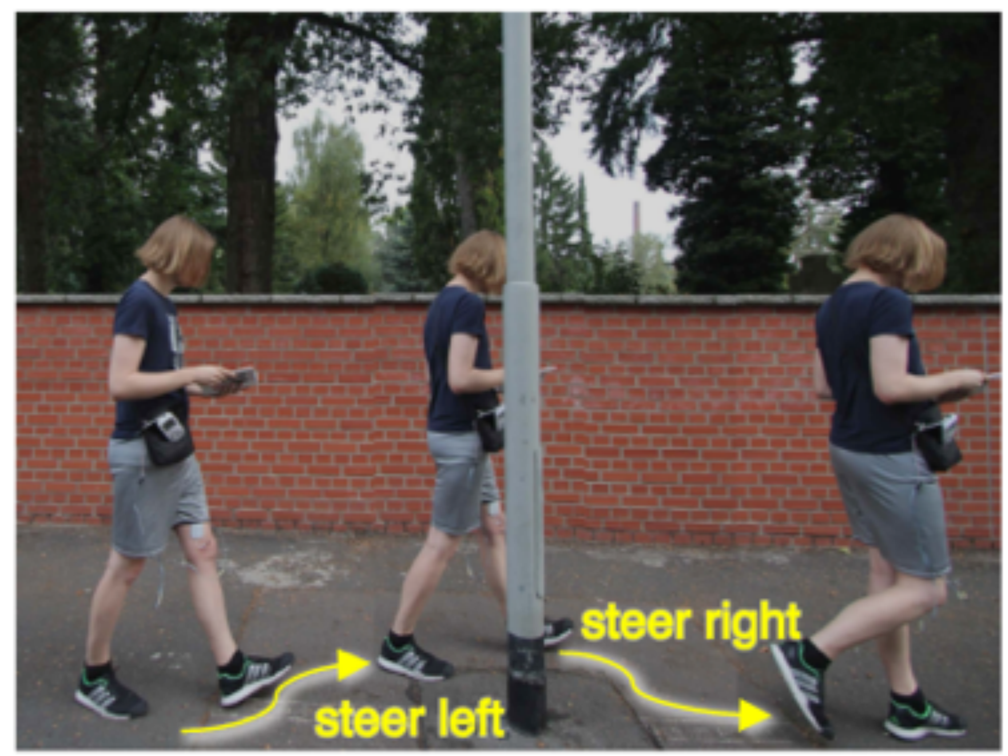



**Figure 1. A user is absorbed in his reading, not noticing the lamppost. Actuated navigation automatically steers him around the obstacle.**

An obvious drawback of such solutions is the need for users to pay attention to navigation feedback, process this information, and transform it into appropriate movements. Moreover, navigation information may be misinterpreted or overlooked

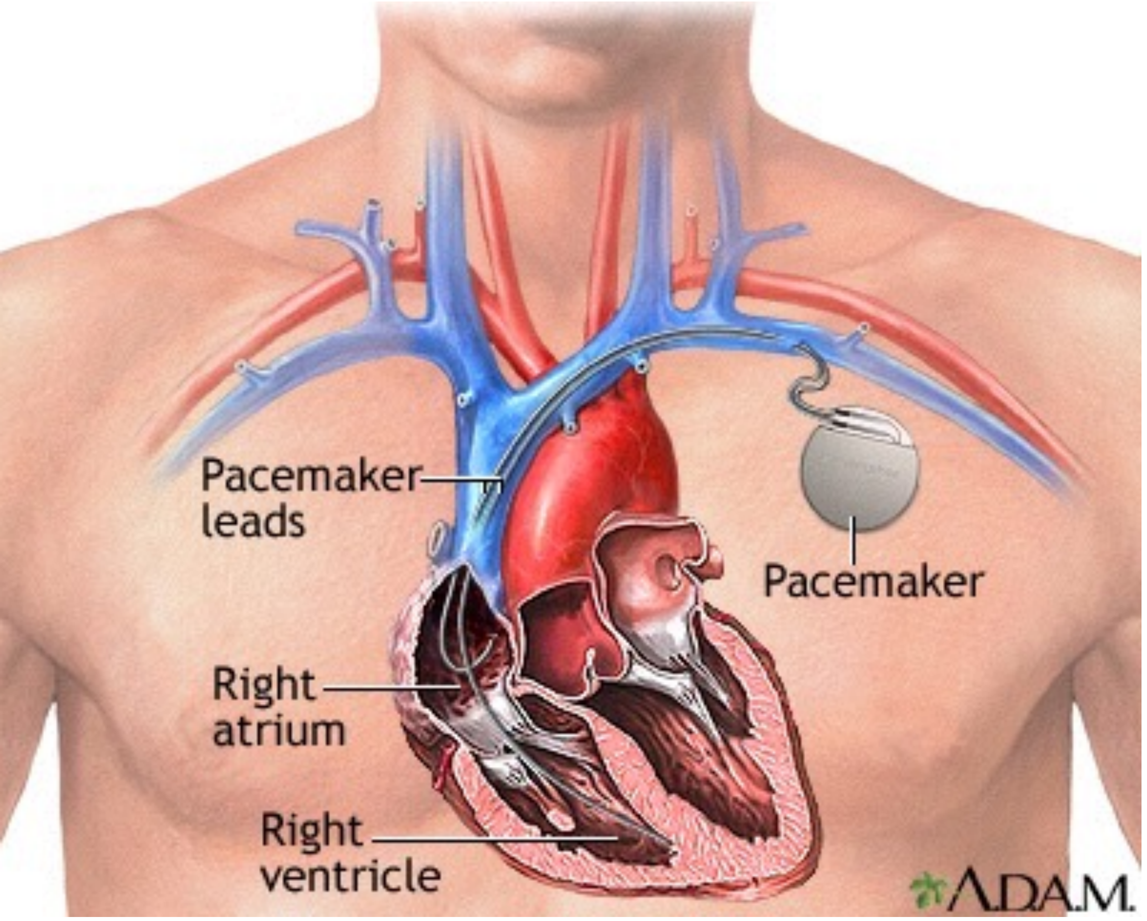
# #3

## implanted interfaces

is this really so far out?

what are **examples** of implanted user interfaces already in use today?

**<30s brainstorming>**




pacemakers…
drug delivery implants…

# Implanted User Interfaces


**Christian Holz**[1,2]
christian.holz@hpi.uni-potsdam.de

**Tovi Grossman**[1], **George Fitzmaurice**[1]
{firstname.lastname}@autodesk.com

**Anne Agur**[3]
anne.agur@utoronto.ca

[1]Autodesk Research
Toronto, Ontario, Canada

[2]Hasso Plattner Institute
Potsdam, Germany

[3]Department of Anatomy
University of Toronto

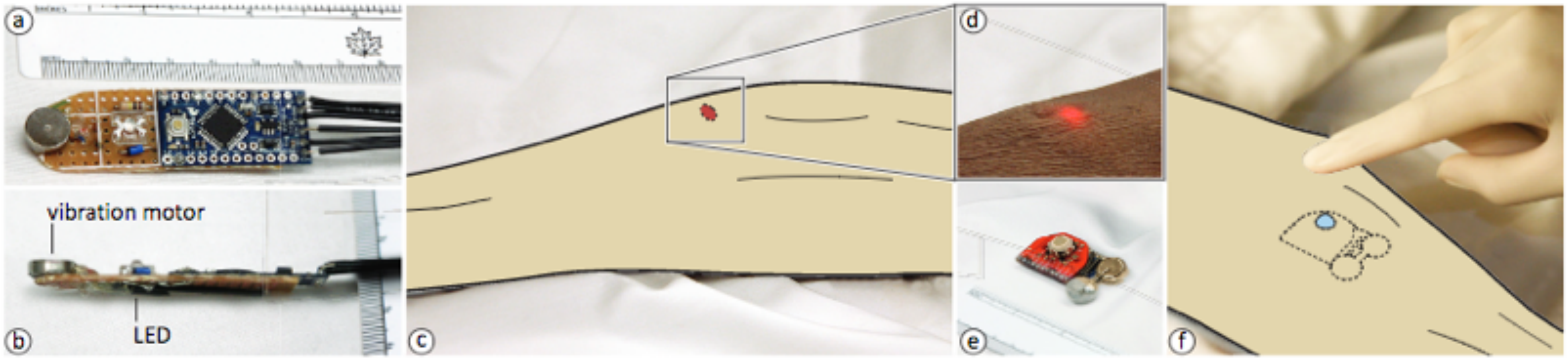




**Figure 1:** ***Implanted user interfaces*** **allow users to interact with small devices through human skin. (a-b) This output device is implanted (c) underneath the skin of a specimen arm. (d) Actual photograph of the LED output through the skin. (e) This standalone prototype senses input from an *exposed* trackball (f) and illuminates it in response. *Note: Throughout this paper, illustrations have been used in place of actual photographs of the specimen, to ensure ethical and professional standards are maintained.***


## ABSTRACT

We investigate *implanted user interfaces* that small devices provide when implanted underneath human skin. Such devices *always* stay with the user, making their implanted user interfaces *available at all times*. We discuss four core challenges of implanted user interfaces: how to sense input through the skin, how to produce output, how to communicate amongst one another and with external infrastructure, and how to remain powered. We investigate these four challenges in a technical evaluation where we surgically implant study devices into a specimen arm. We find that traditional interfaces do work through skin. We then demonstrate how to deploy a prototype device on participants, using artificial skin to simulate implantation. We close with a discussion of medical considerations of implanted user interfaces, risks and limitations, and project into the future.



## Author Keywords


tinguishable from it" [47]. Weiser's seminal vision is close to becoming today's reality. We now use mobile devices to place calls and send emails on the go, maintain our calendars and setup reminders, and quickly access information. While these devices have not yet disappeared, they have become an integral part of our lives, to the point where we have arguably become dependent on them [14]. For example, in a recent survey of 200 Stanford students that owned iPhones, nearly a quarter of those surveyed reported that the iPhone felt like an extension of their brain or body [28].

In this paper, we propose manifesting these dependencies on external devices by implanting them underneath human skin, allowing users to interact with them through *implanted user interfaces*. While implanted devices have existed for a long time in the medical domain, such as hearing aids or pacemakers, they support only limited interaction, and cannot support personal tasks. Unlike other types of mobile devices, such as wearables [40] or interactive clothing [33],


**1998:** Kevin Warwick: Project Cyborg

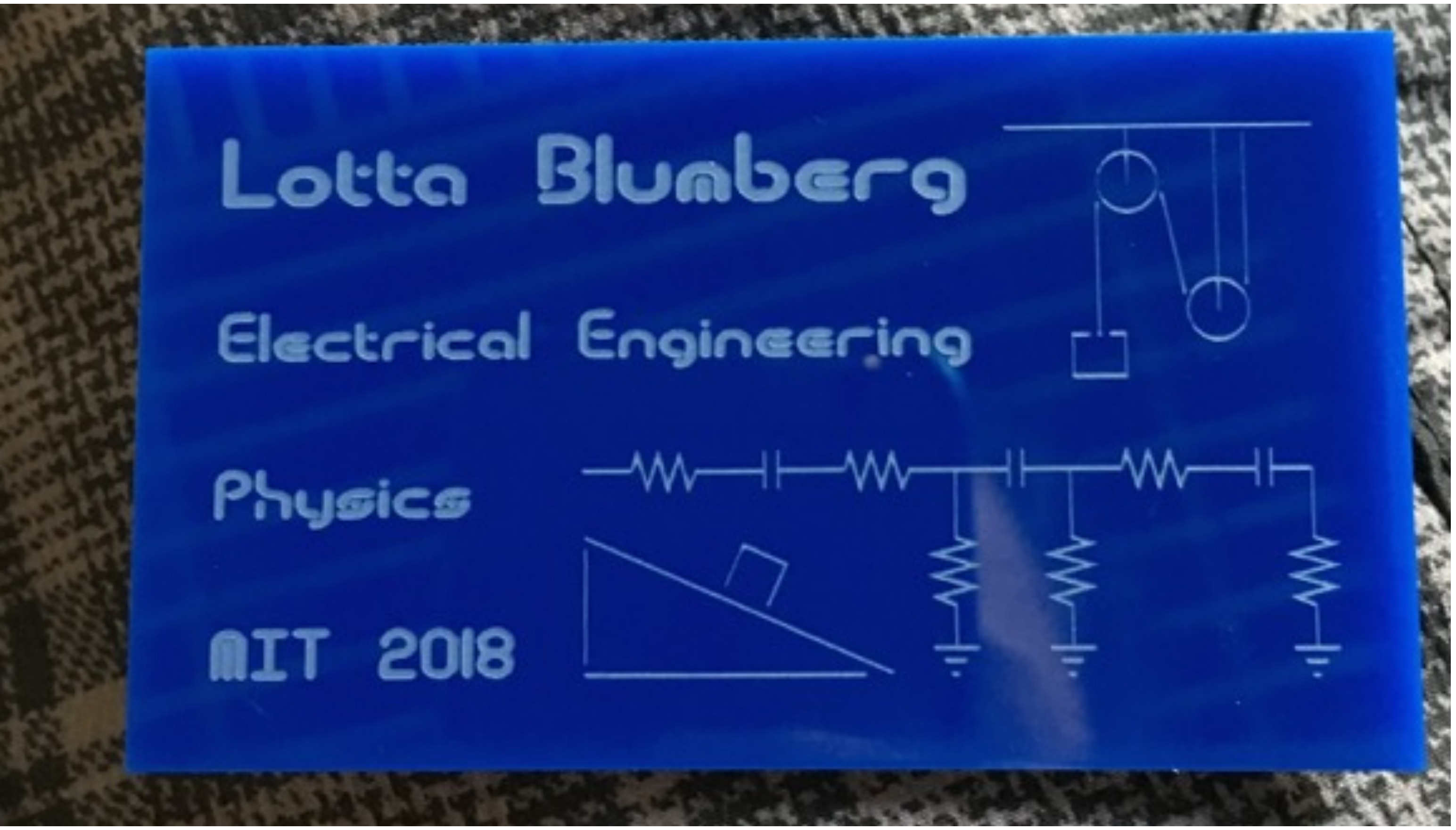
# summary

## the body as an interface::

- brain computer interfaces
- muscle computer interfaces
- implanted interfaces

# results from HW1

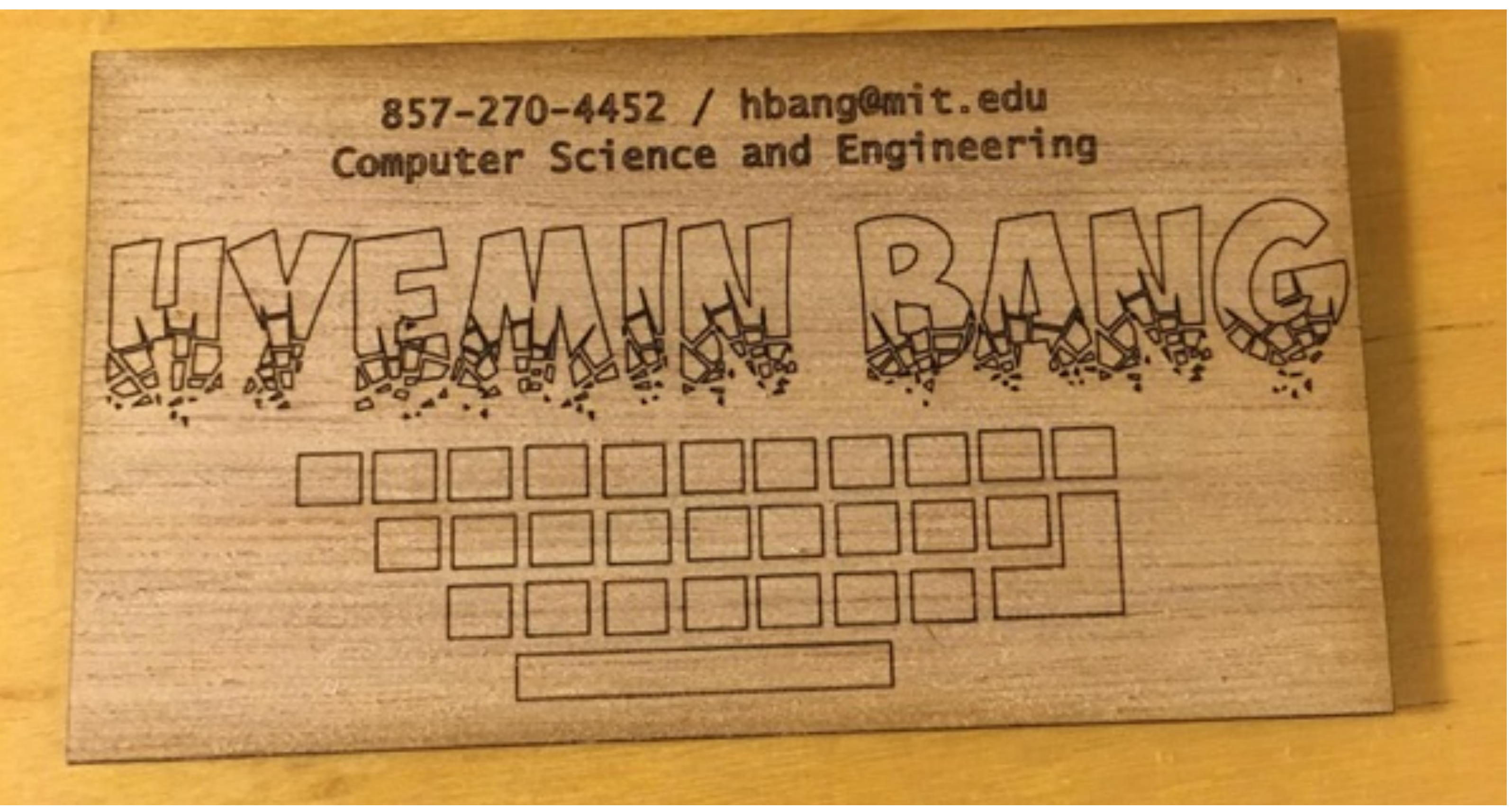




# rock :)!

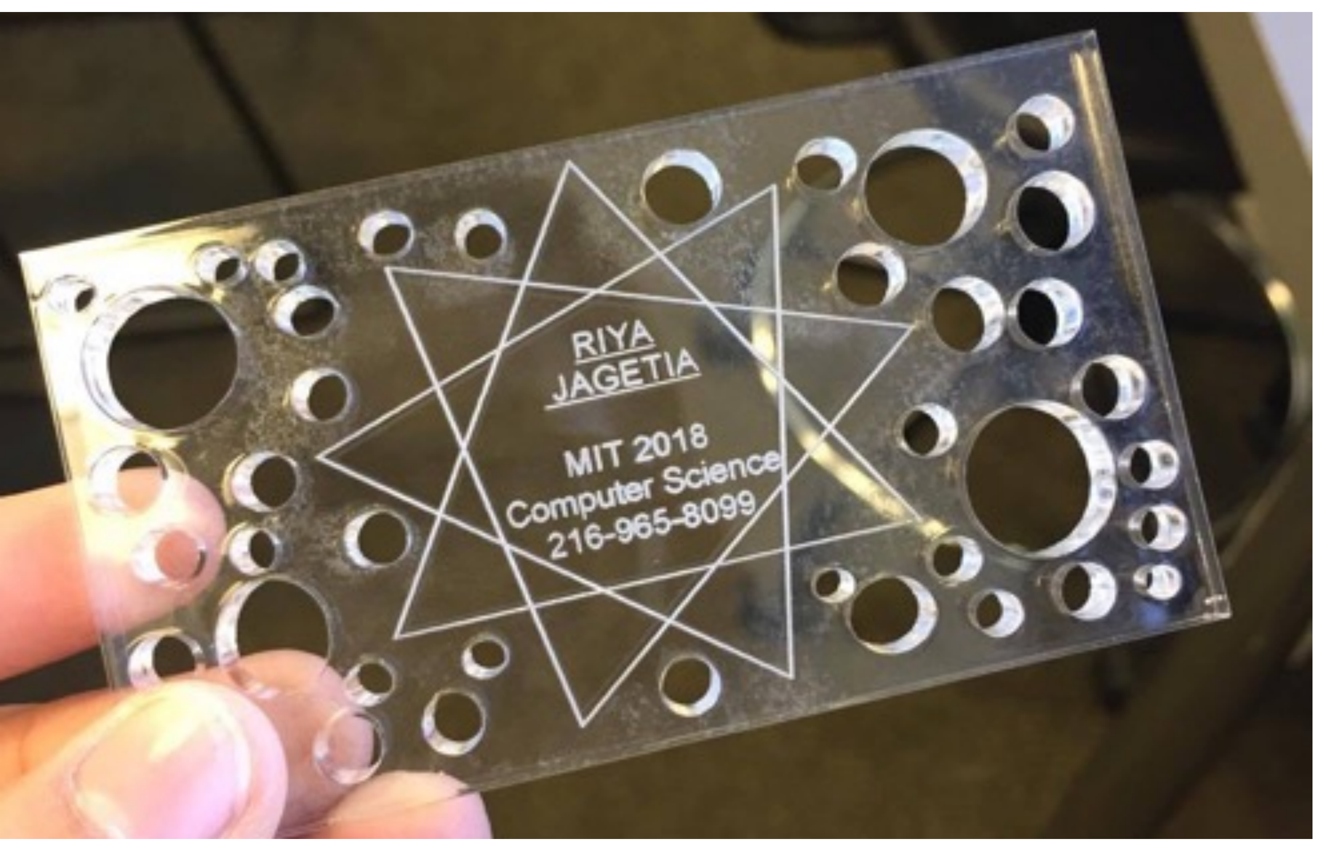
let's show your card to your neighbors


# rock :)!

let’s show your card to your neighbors






# rock :)!

let’s show your card to your neighbors


rock :)!


let’s show your card to your neighbors

end.