Aalto University

Intelligent User Interfaces Studio

ELEC-E7870 - Advanced Topics in User Interfaces
10.02.2018

Kashyap Todi & Sunjun Kim

Before we start…

Mario Time!

Lecture 4:
Activation Point

Principles

Human sensory system

Cue integration

Button activation
based on human perception

Lecture 4: Activation Point 1) Background

Repp, Bruno H. "Sensorimotor synchronization: a review of the tapping literature." *Psychonomic bulletin & review* 12.6 (2005): 969-992.

Repp, Bruno H., and Yi-Huang Su. "Sensorimotor synchronization: a review of recent research (2006–2012)." *Psychonomic bulletin & review* 20.3 (2013): 403-452.

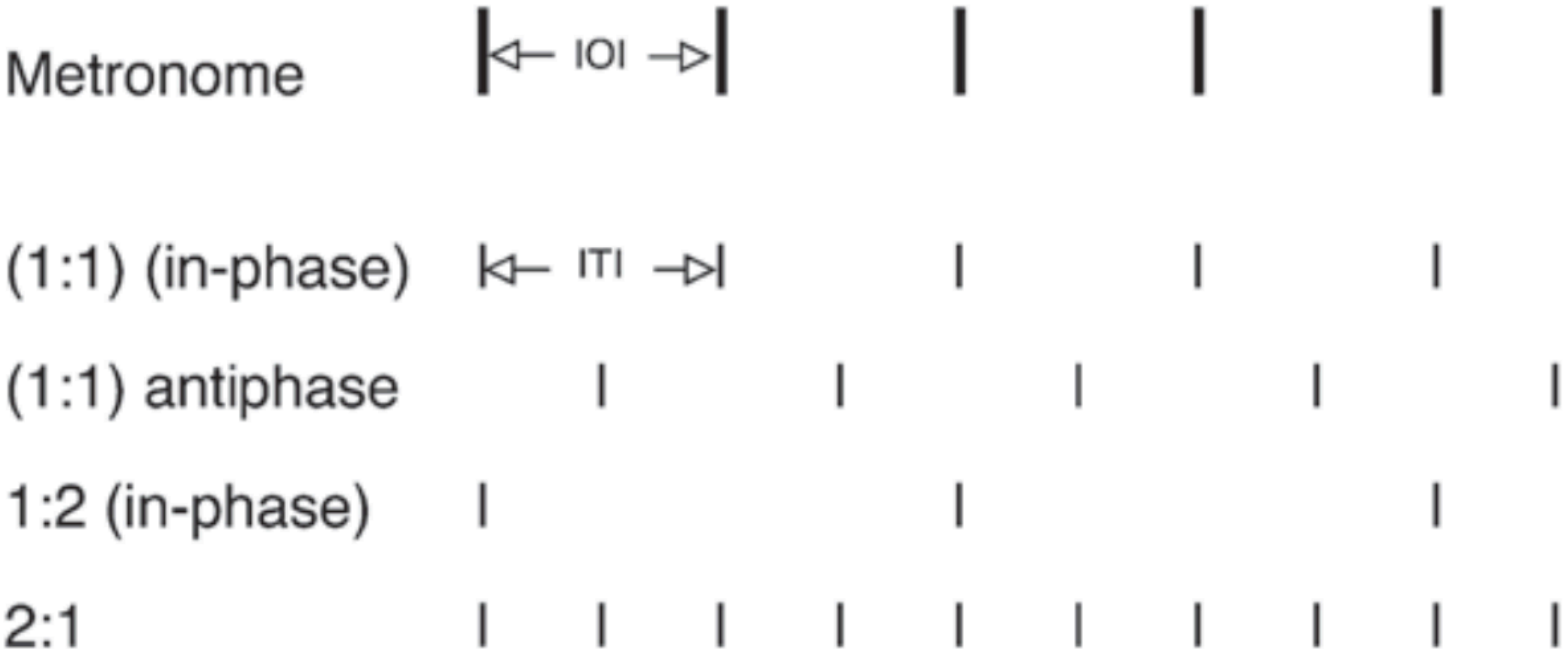
Oulasvirta, Antti, Sunjun Kim, and Byungjoo Lee. "Neuromechanics of a Button Press." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Ernst, Marc O. "A Bayesian view on multimodal cue integration." *Human body perception from the inside out* 131 (2006): 105-131.

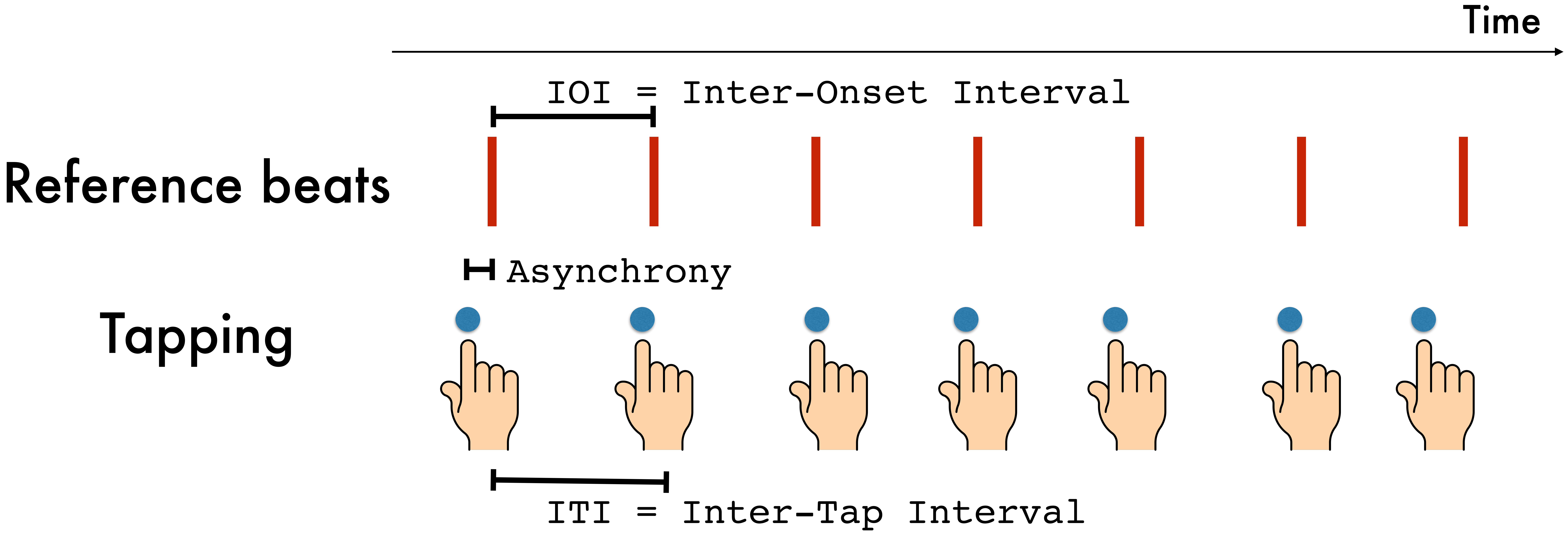
Listen and ***tap*** to the rhythm

Sensorimotor synchronization

= SMS := "the coordination of rhythmic movement with an external rhythm"



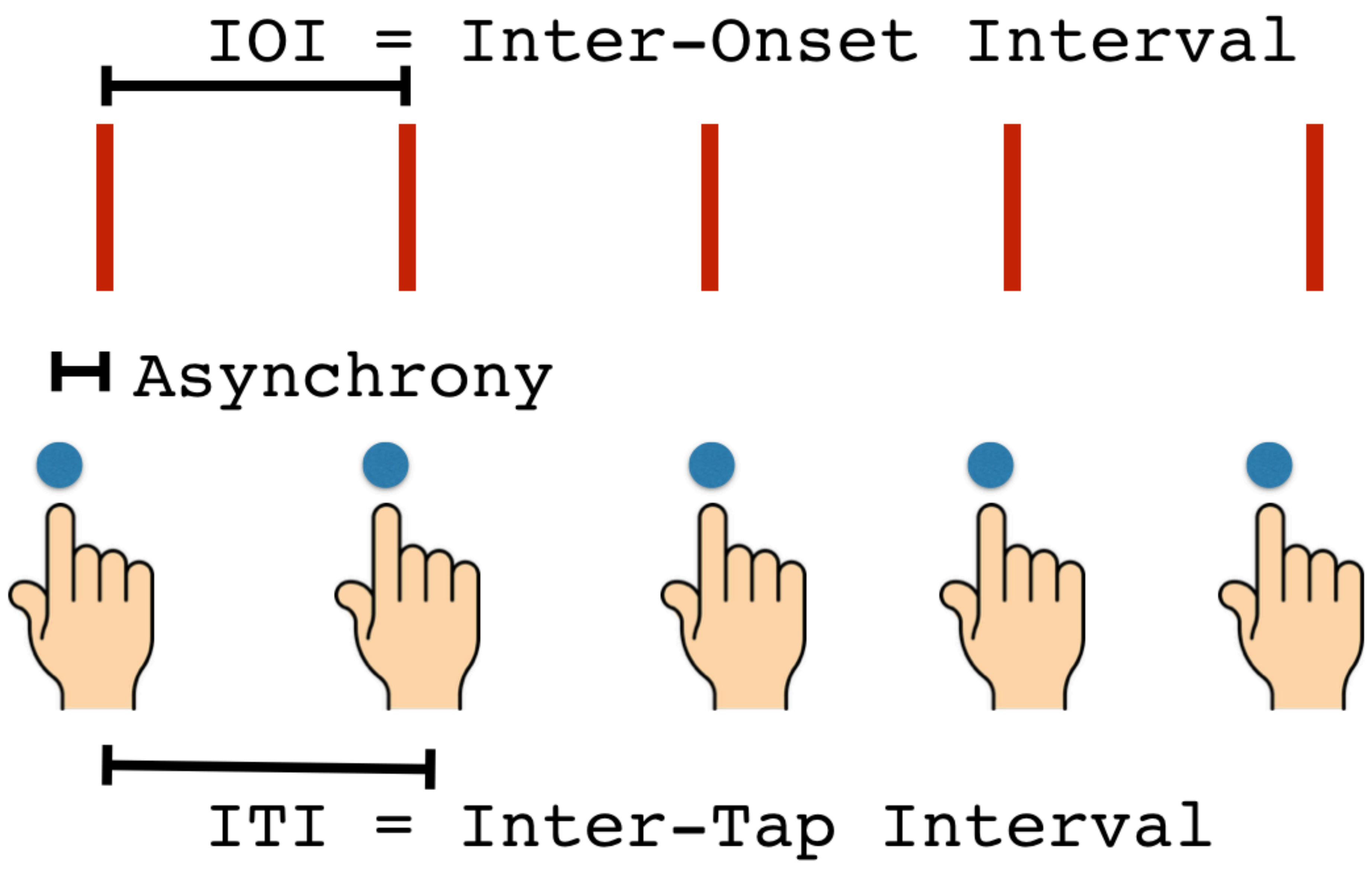
Terminologies



Mesures

- Accuracy
  - Mean of the ITI
  - Mean of the Asynchrony
    - Signed Asynchrony
    - Absolute Asynchrony

- Variability
  - SD of the ITI
  - Coefficient of Variation of the ITI (= SD/Mean)
  - SD of asynchrony

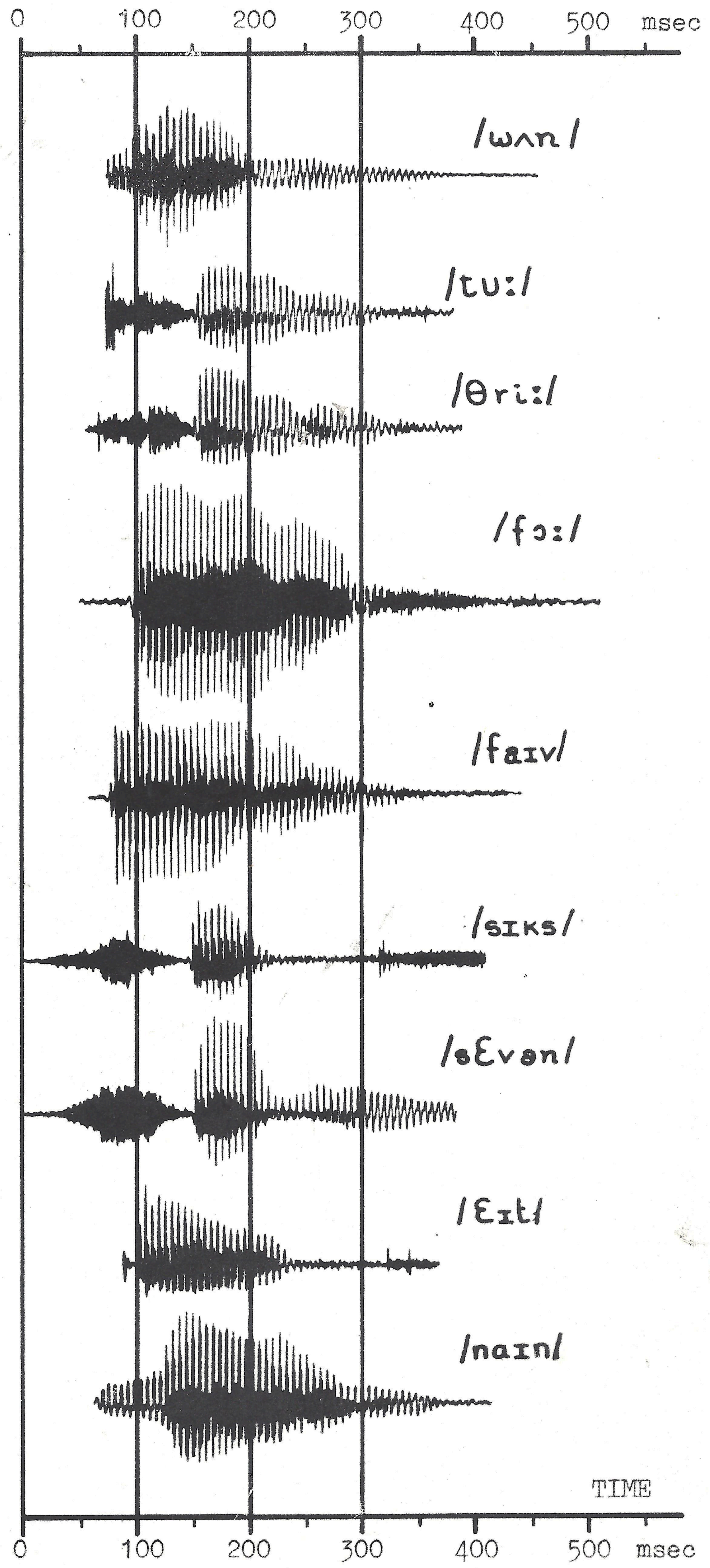


Morton, John, Steve Marcus, and Clive Frankish. "Perceptual centers (P-centers)." *Psychological Review* 83.5 (1976): 405.

P-center

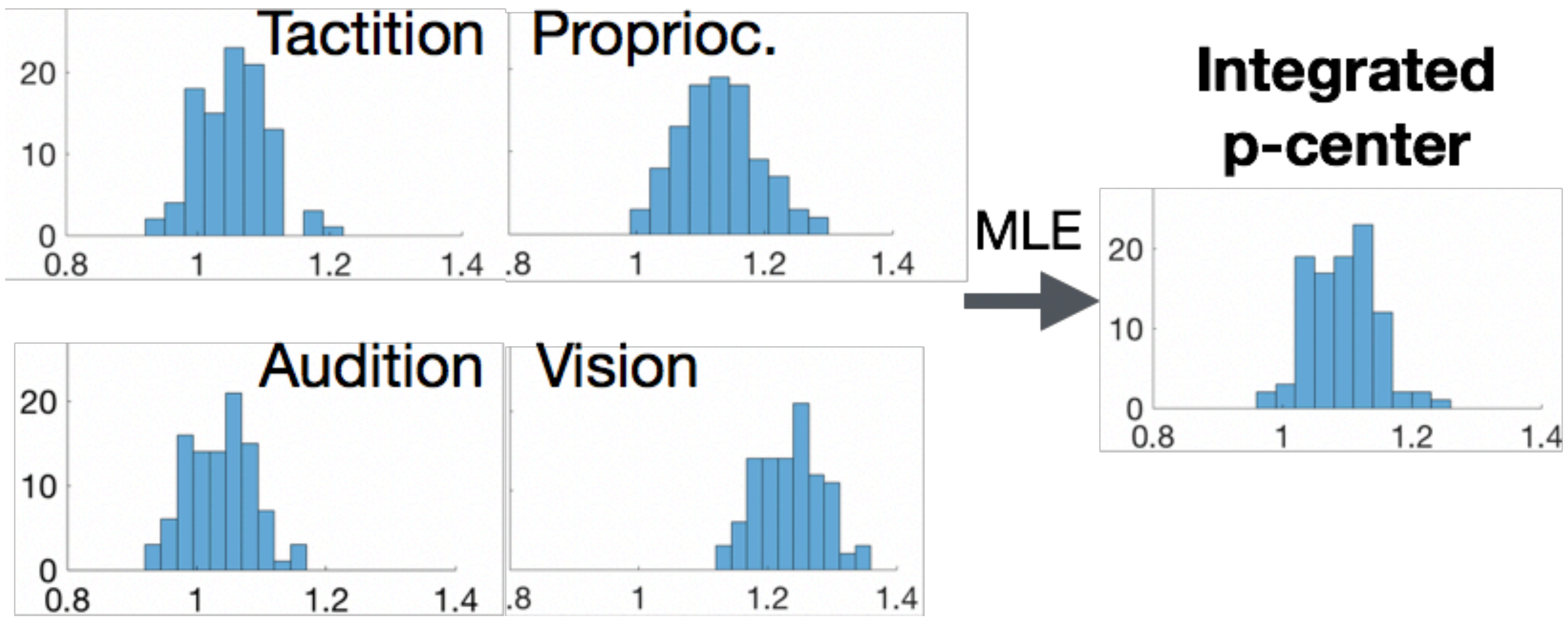
:= *"the time points at which auditory events are perceived to occur"*

A human ability to abstract a series of cues into a point event.



Oulasvirta, Antti, Sunjun Kim, and Byungjoo Lee. "Neuromechanics of a Button Press." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

P-center of button press

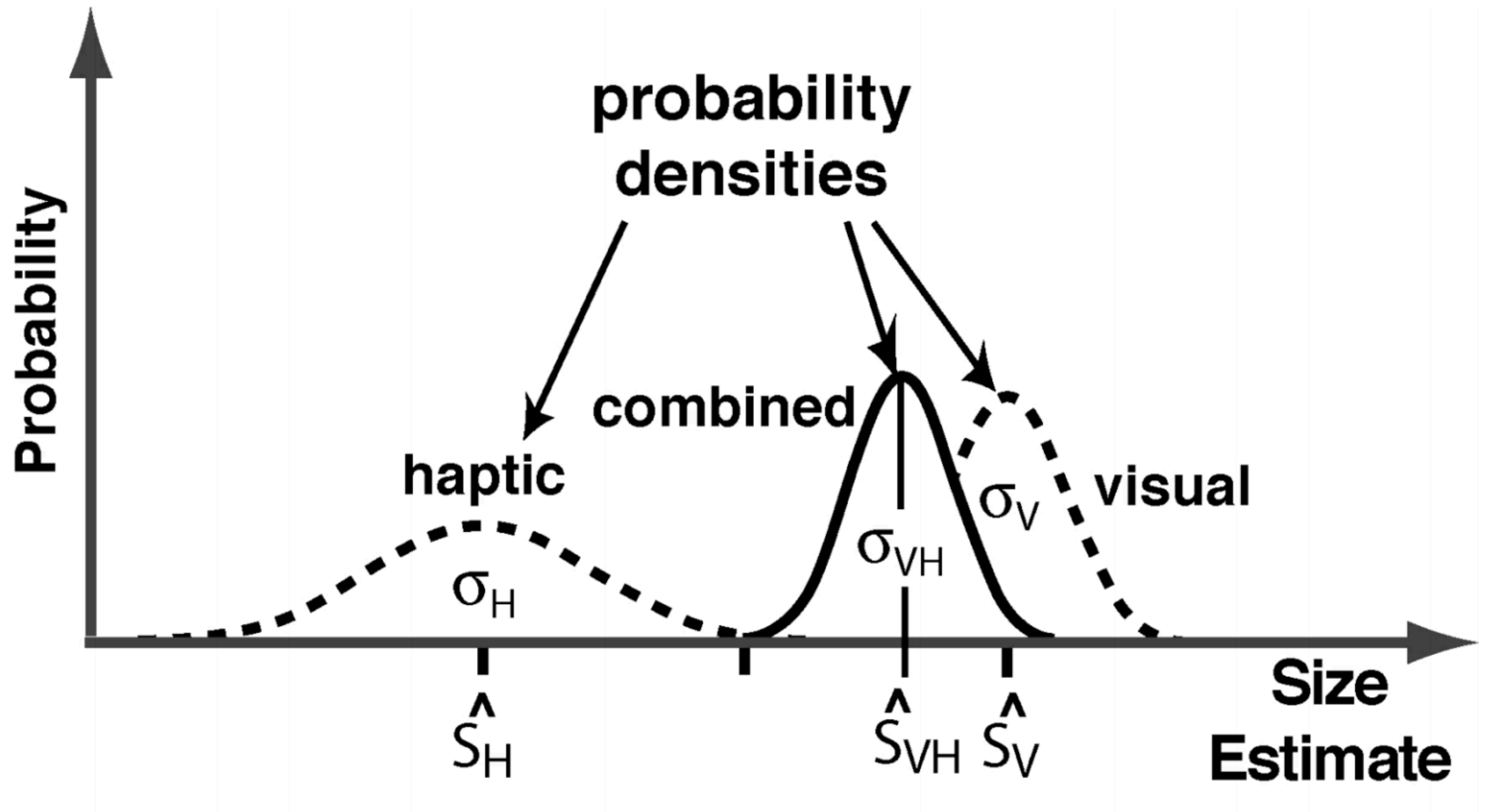


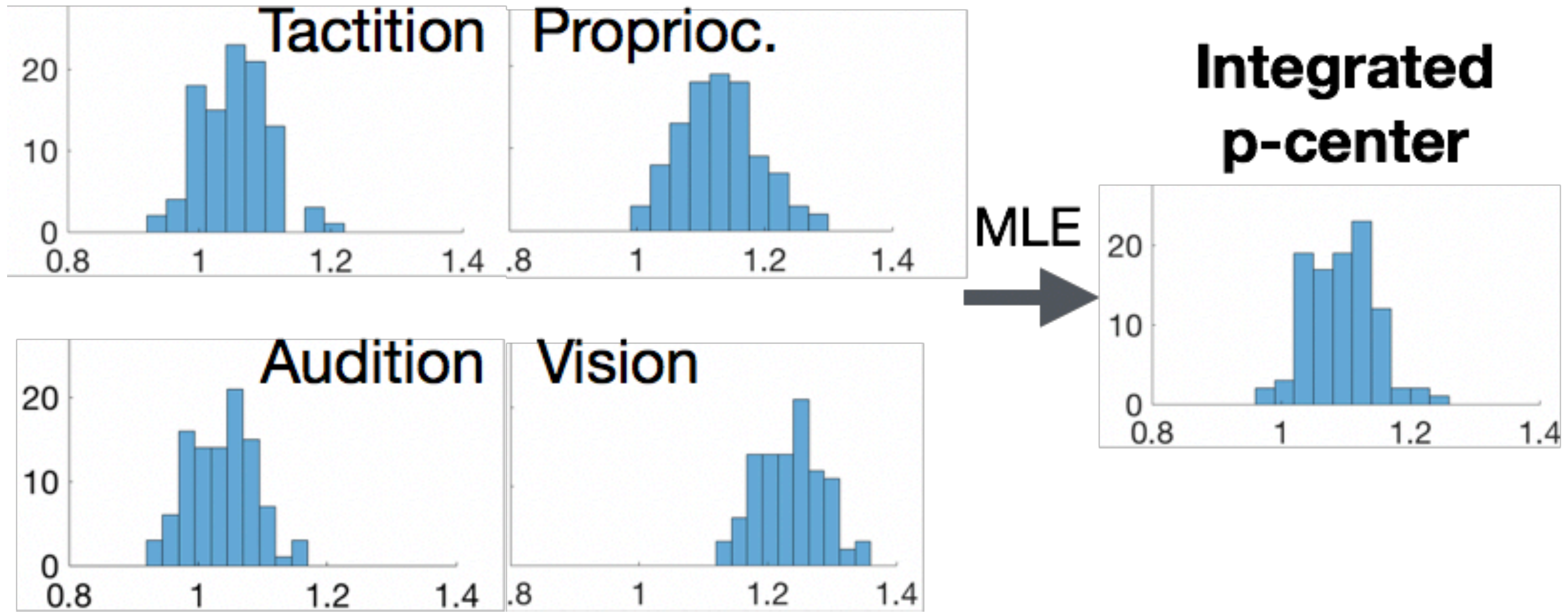
→ The result of integration of multimodal cues.

Assumption: cues are integrated using Maximum Likelihood Estimation.
= Cue Integration Theory

Ernst, Marc O. "A Bayesian view on multimodal cue integration." *Human body perception from the inside out* 131 (2006): 105-131.

Cue Integration Theory





$$pc_o = \sum_i w_i pc_i \text{ where } w_i = \frac{1/\sigma_i^2}{\sum_i 1/\sigma_i^2}$$

https://www.khanacademy.org/science/health-and-medicine/nervous-system-and-sensory-infor/somatosensation-topic/v/somatosensation-1

Somatosensation

Sensory system of recognizing extra environment through *touch*.
+ Awareness of body position and movement (proprioception)

Type

Temperature (=Thermoreception)

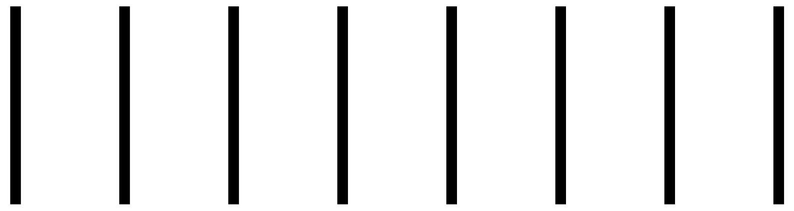
Pressure (=Mechanoreception)

Pain (=Nociception)

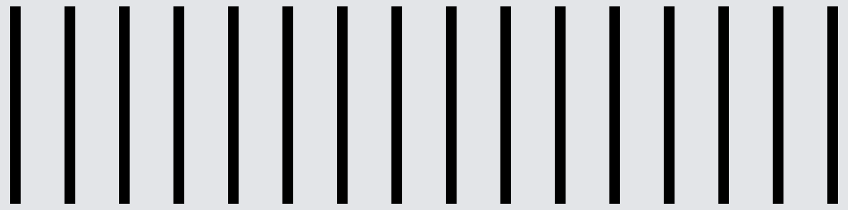
Position (=Proprioception)

Intensity coding (nerve firing)

Weak = sparse

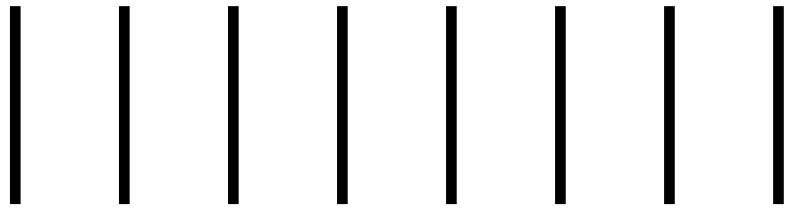


Intense: frequent

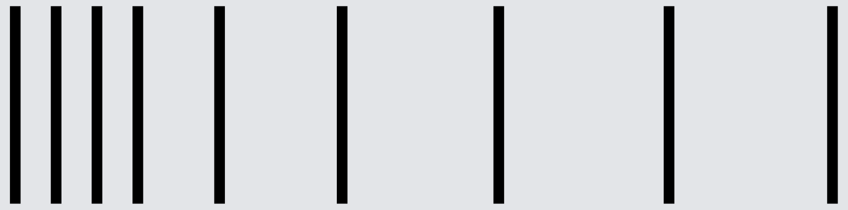


Adaptation (timing)

Non-adapting



Slow-adapting

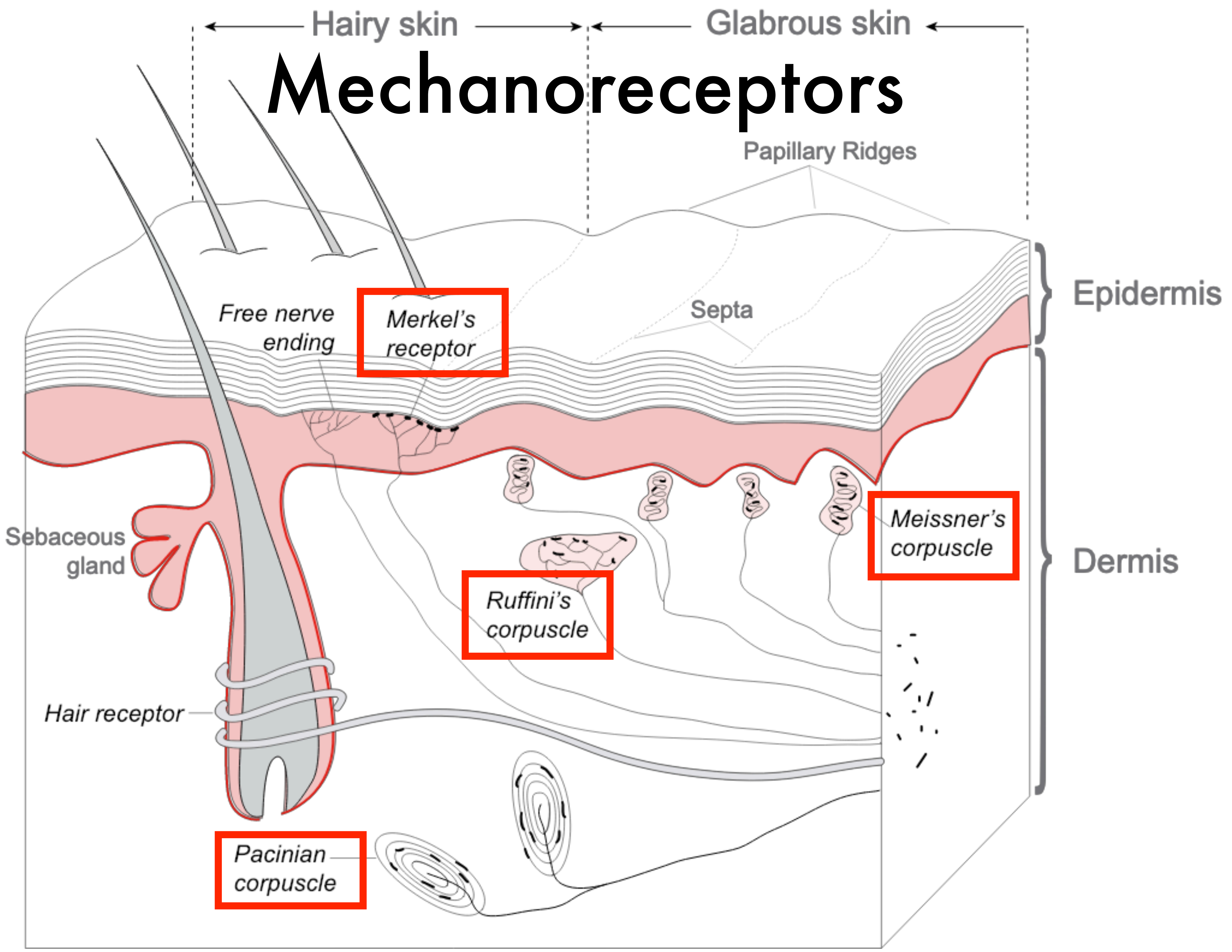


Fast-adapting

Somatosensory receptors for button-pressing

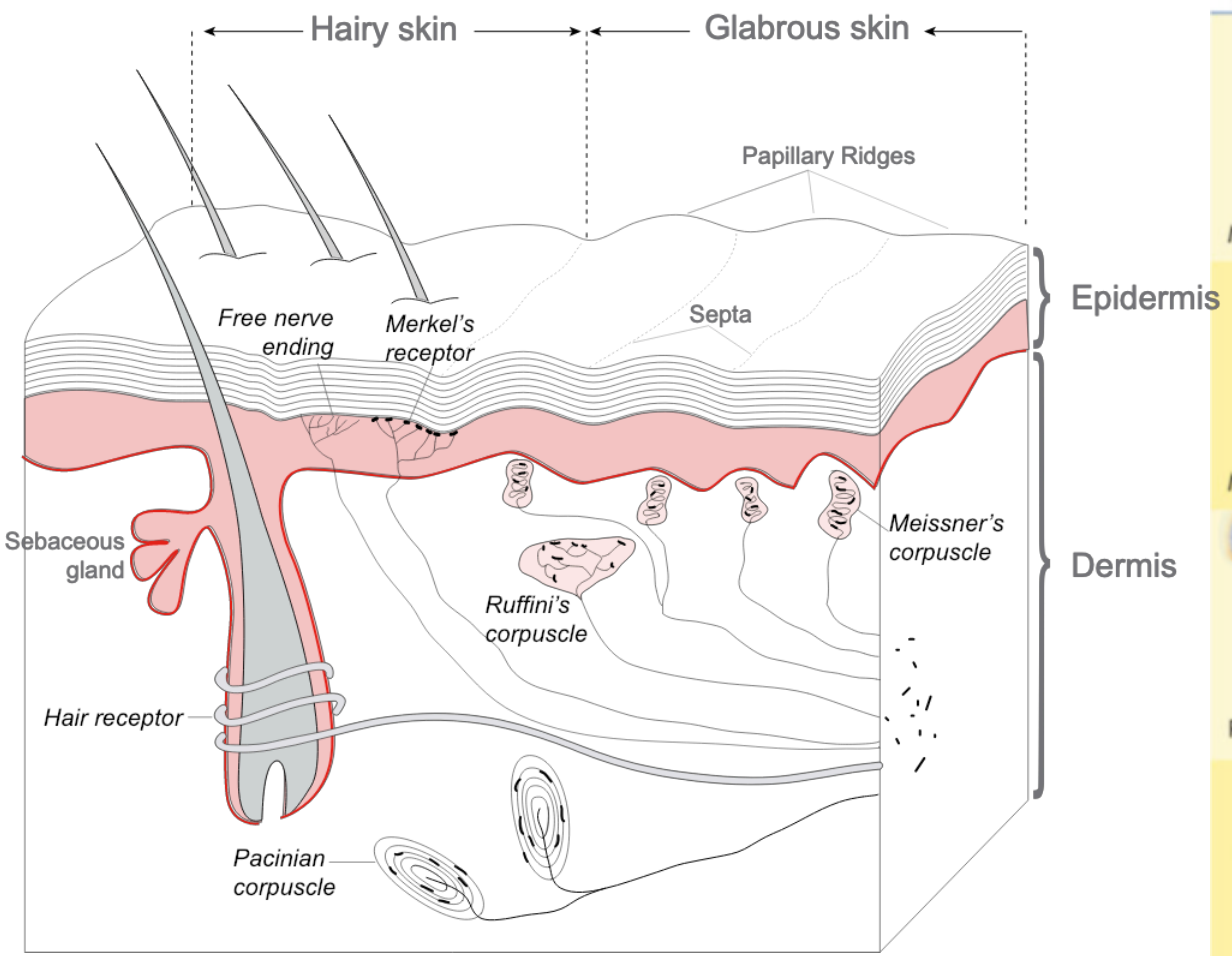
Tactile stimuli (→ mechanoreceptors) and kinesthetic stimuli (→ proprioceptor)

Type
Temperature (=Thermoreception)
Pressure (=Mechanoreception)
Pain (=Nociception)
Position (=Proprioception)



Thomas.haslwanter [CC BY-SA 3.0], from Wikimedia Commons

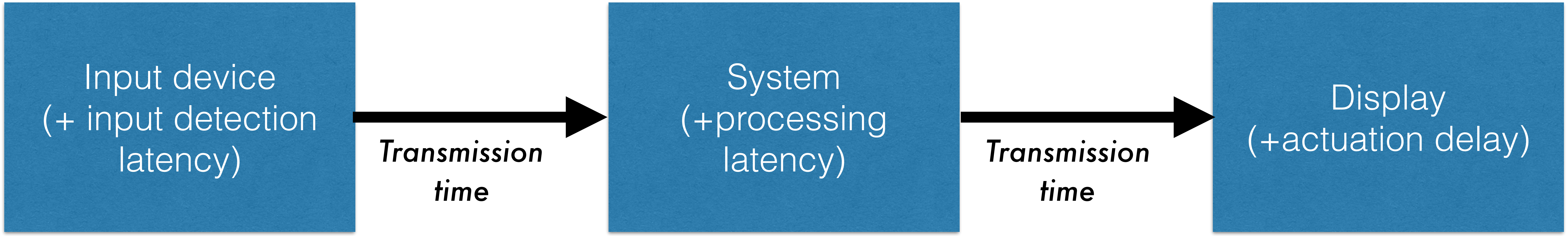
Mechanoreceptors



Receptor (Fiber)	How Fiber Responds	Frequency Response	Perceptions
Merkel (SA1)	Continuous (slow adapting)	0.3–3 Hz Slow pushing	Fine details
Meissner (RA1)	On Off Responds to change (rapid adapting)	3–40 Hz	"Flutter" Hand-grip control (tools)
Ruffini (SA2)	Continuous (slow adapting)	15–400 Hz	Stretching
Pacinian (RA2)	Responds to change (rapid adapting)	10–500 Hz Rapid vibration at upper range	Vibration Texture by moving fingers

Properties of Four Types of Mechanoreceptors. Thomson Higher Education, 2007. Table 14.1

Input device latency



- **Keyboard**: 2--40 ms device delay ➝ <10 ms system processing and transmission delay ➝ 10-50 ms display delay
  ➔ 12 -- 100 ms end-to-end latency.
- **Mouse**: 2--40 ms device delay ➝ <10 ms system processing and transmission delay ➝ 10-50 ms display delay
  ➔ 15 -- 100 ms end-to-end latency.
- **Touchscreen**: 10-45 ms device delay ➝ <10 ms system processing and transmission delay ➝ 10-50ms display delay
  ➔ 20 -- 105 ms end-to-end latency.

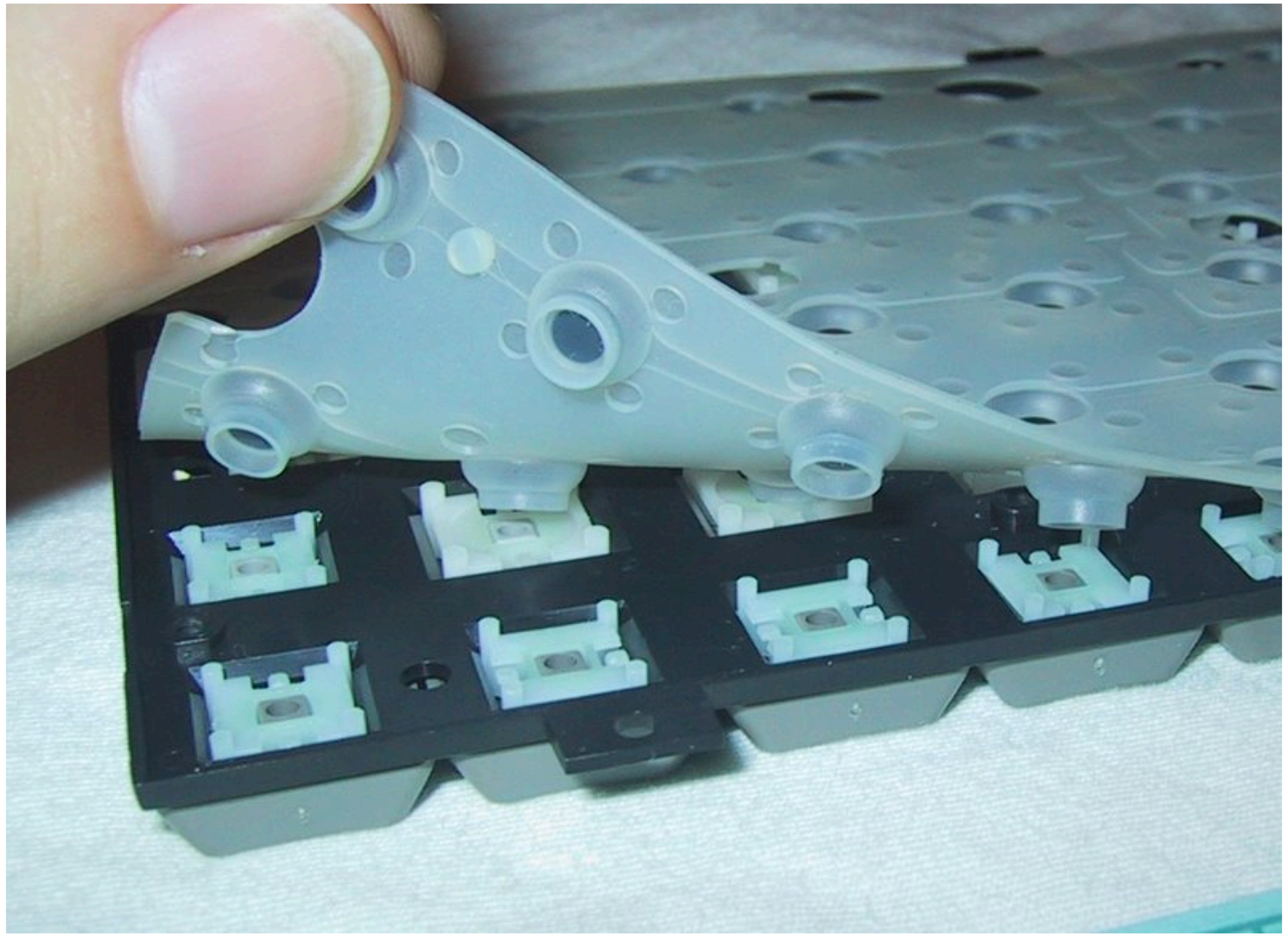
Lecture 4:
Activation Point
2) Button Activation

Goal of a button press


Esc

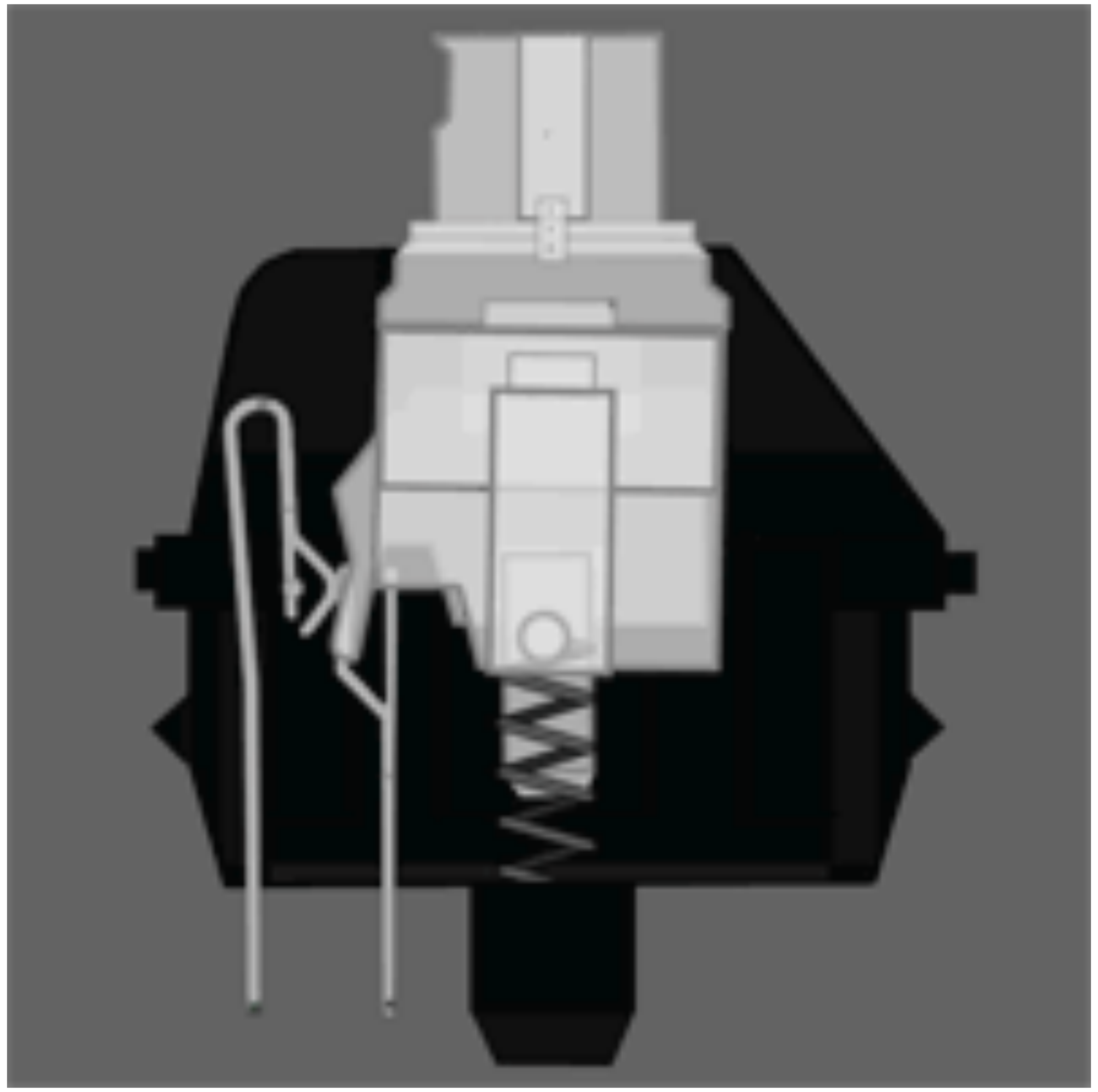
Button Structure

- Rubber-dome actuator



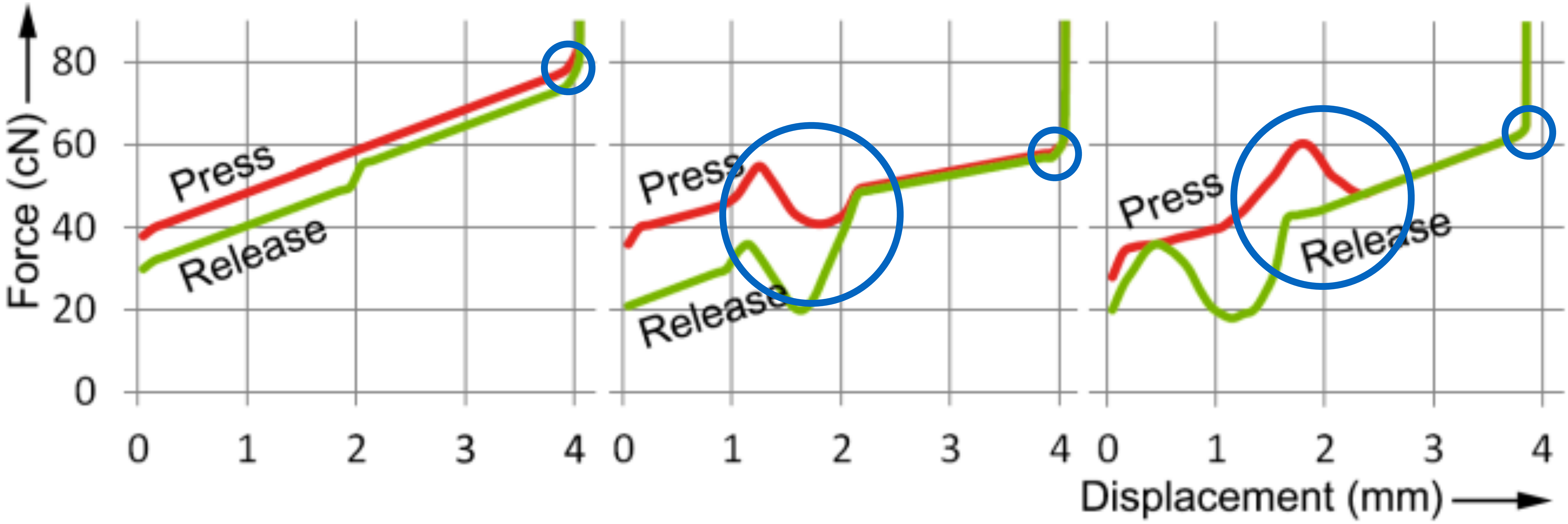
Button Structure

- Mechanical slider-spring-contact

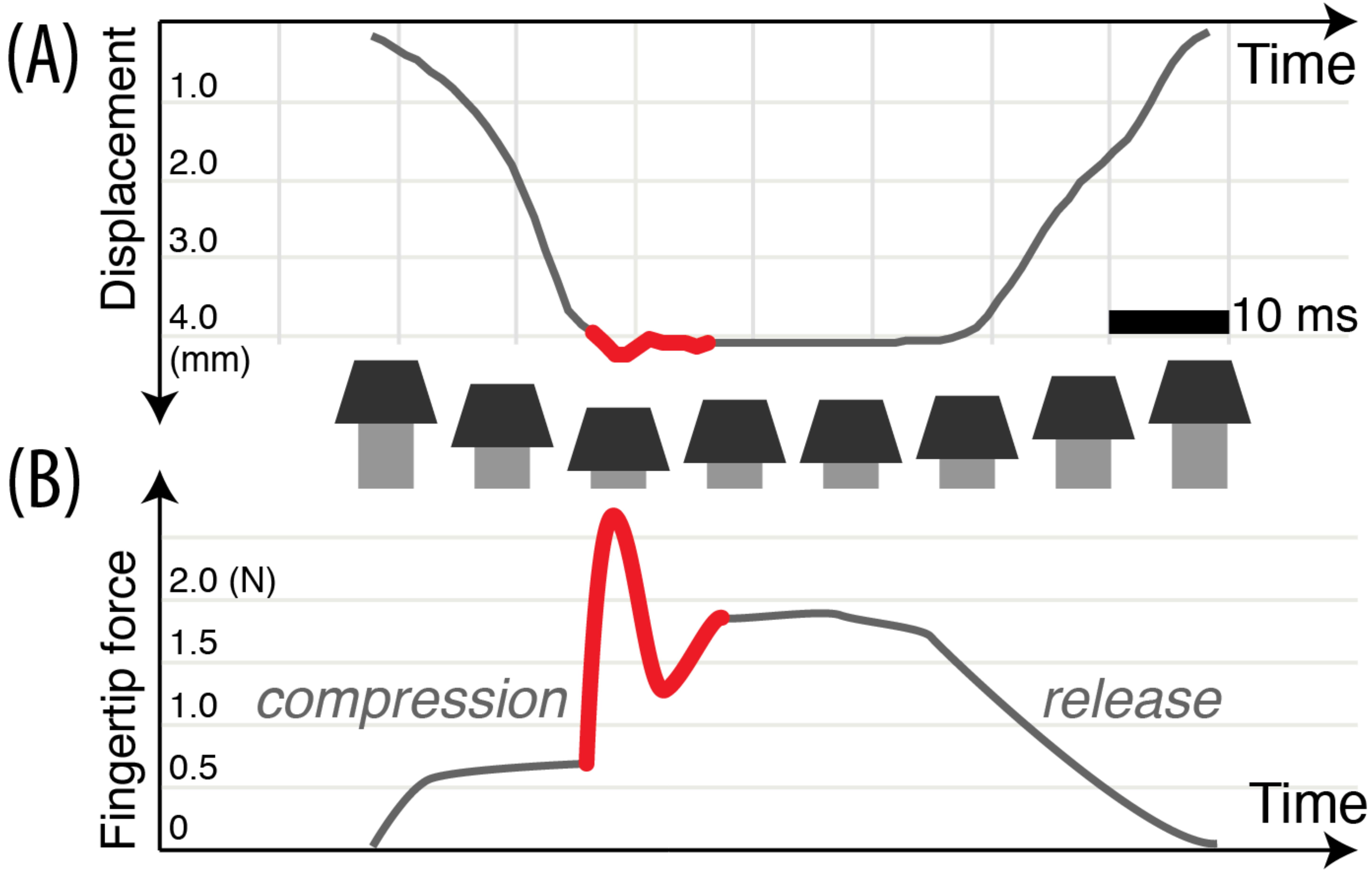


https://www.keyboardco.com/blog/index.php/2012/12/an-introduction-to-cherry-mx-mechanical-switches/

Force-Displacement Curve

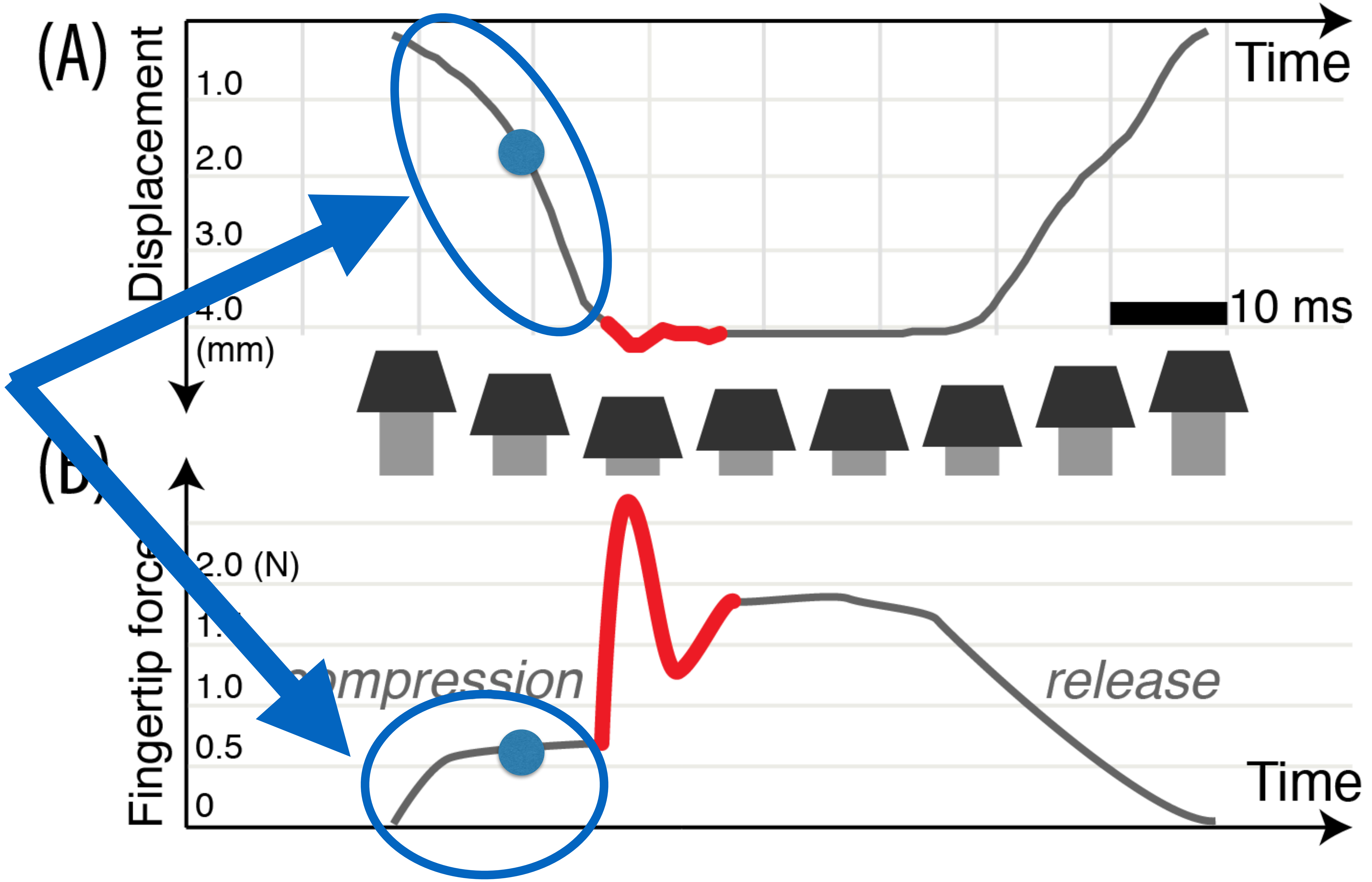


A decomposition of a button press

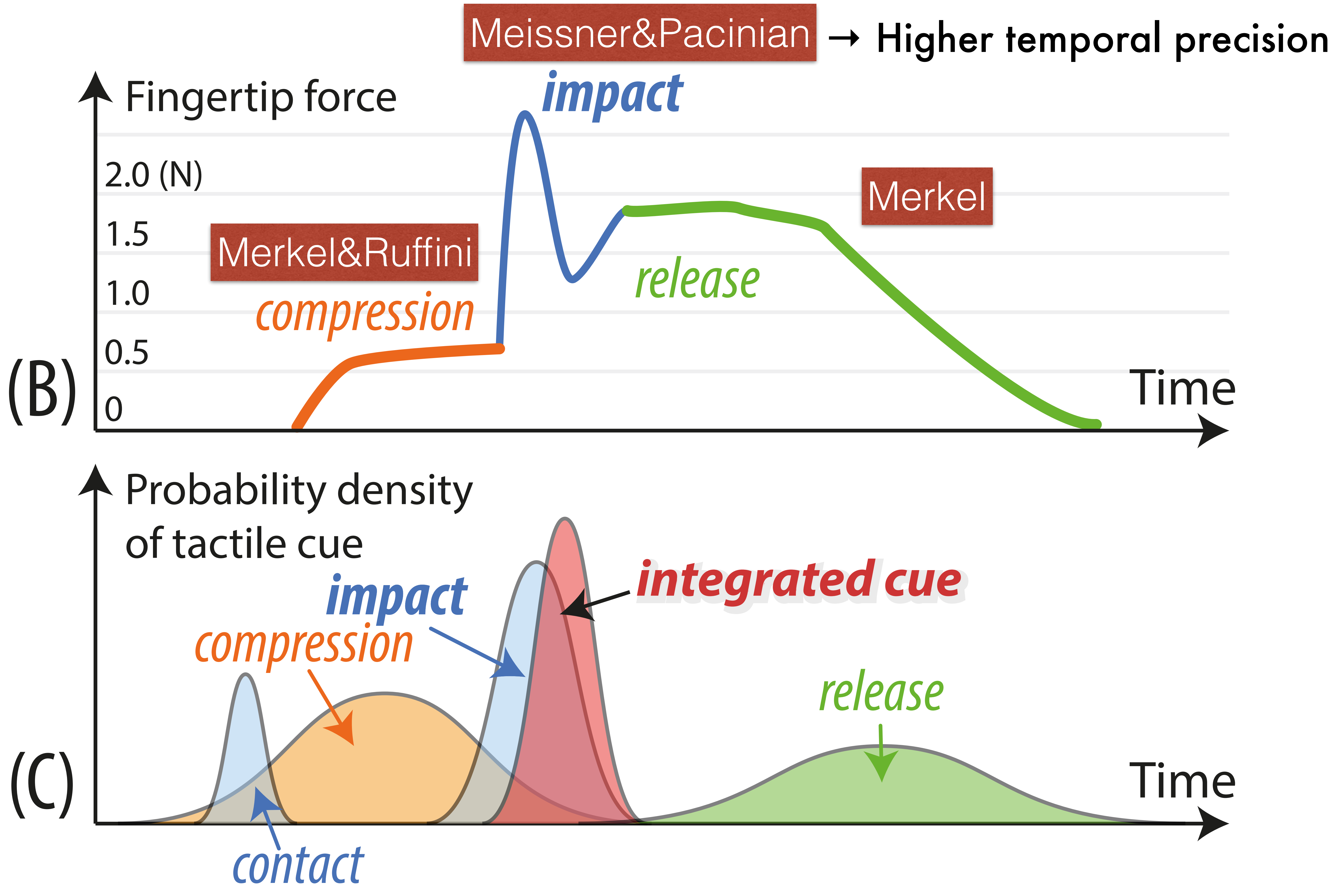


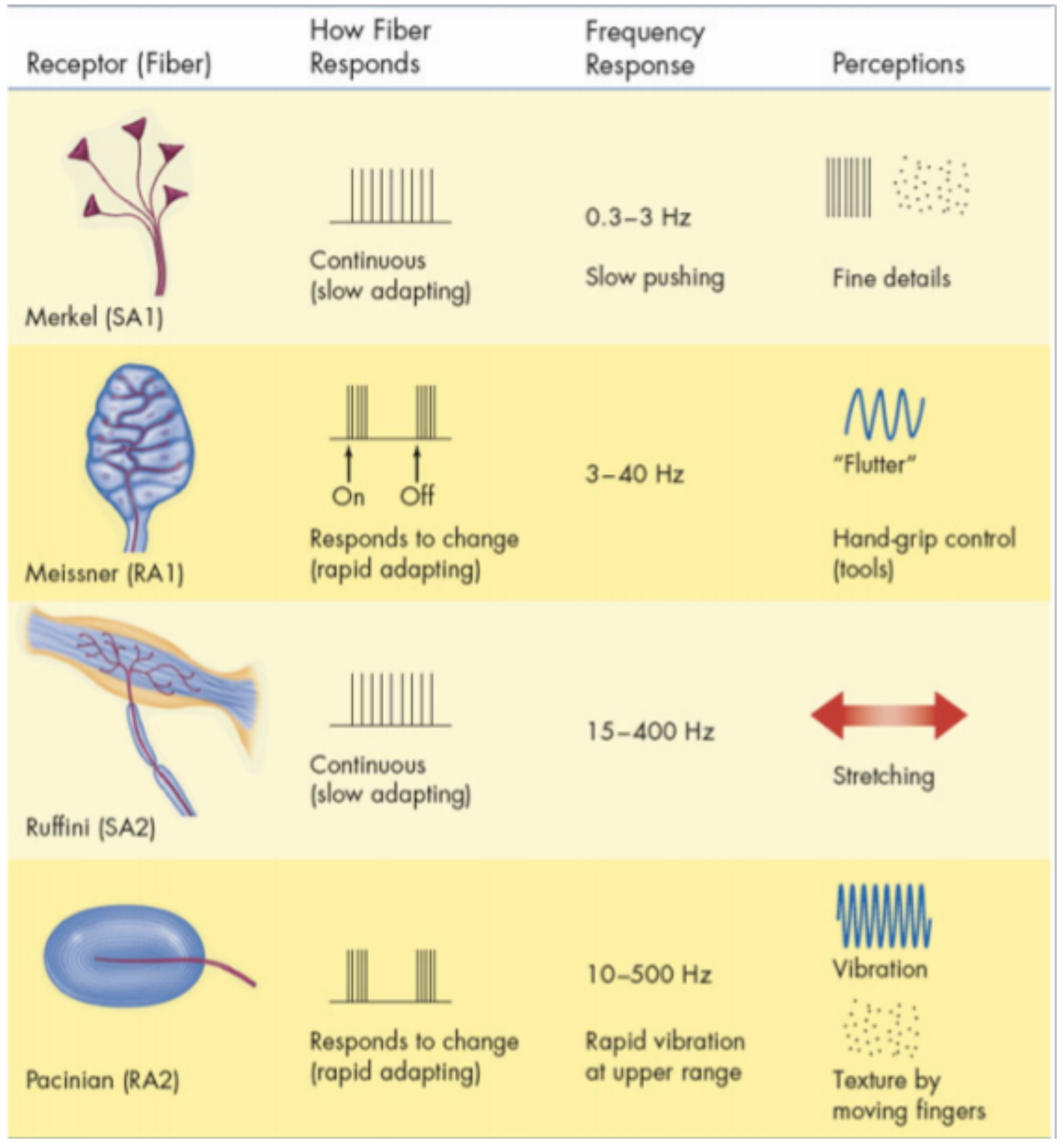
A decomposition of a button press

Activation Point
:= The moment of
input registration



Cue Integration in Button Press





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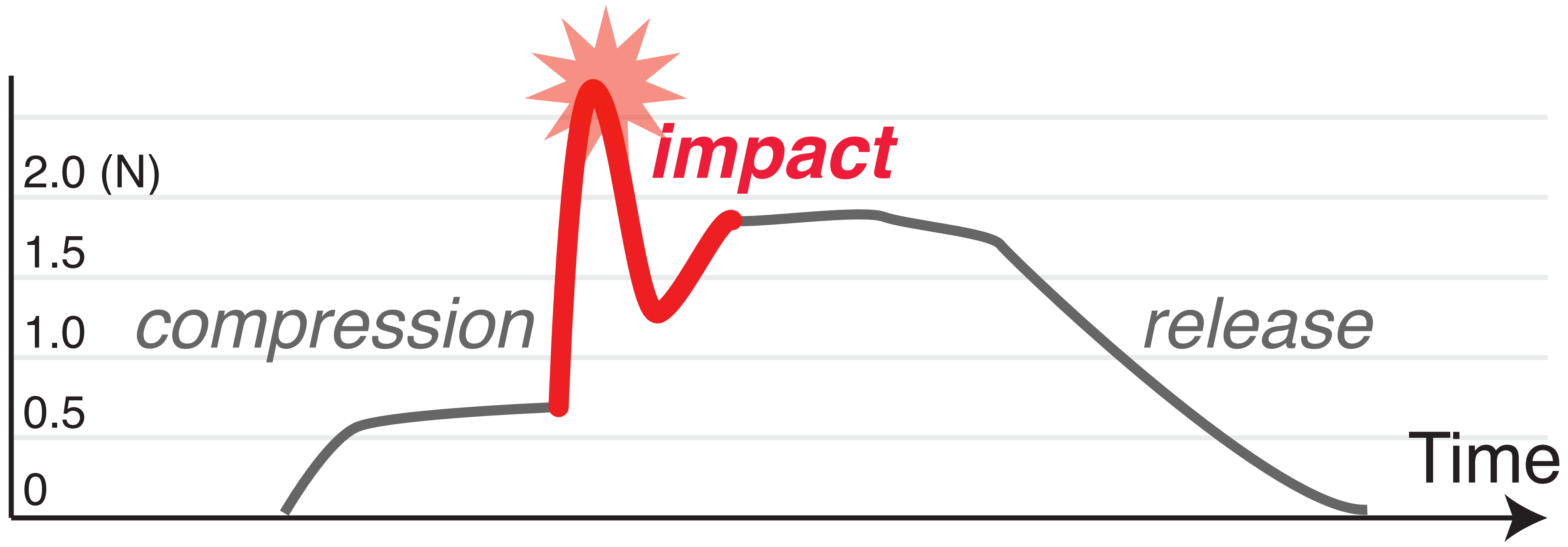
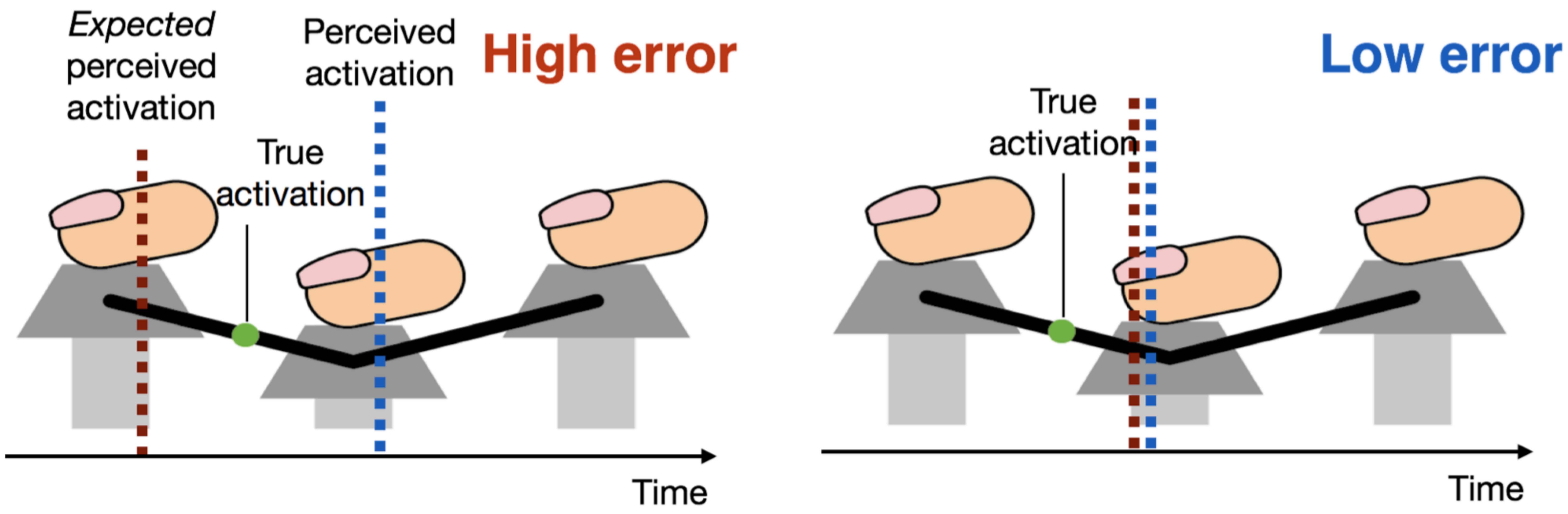
Impact Activation

- Principle: input registration align with the integrated tactile cue.

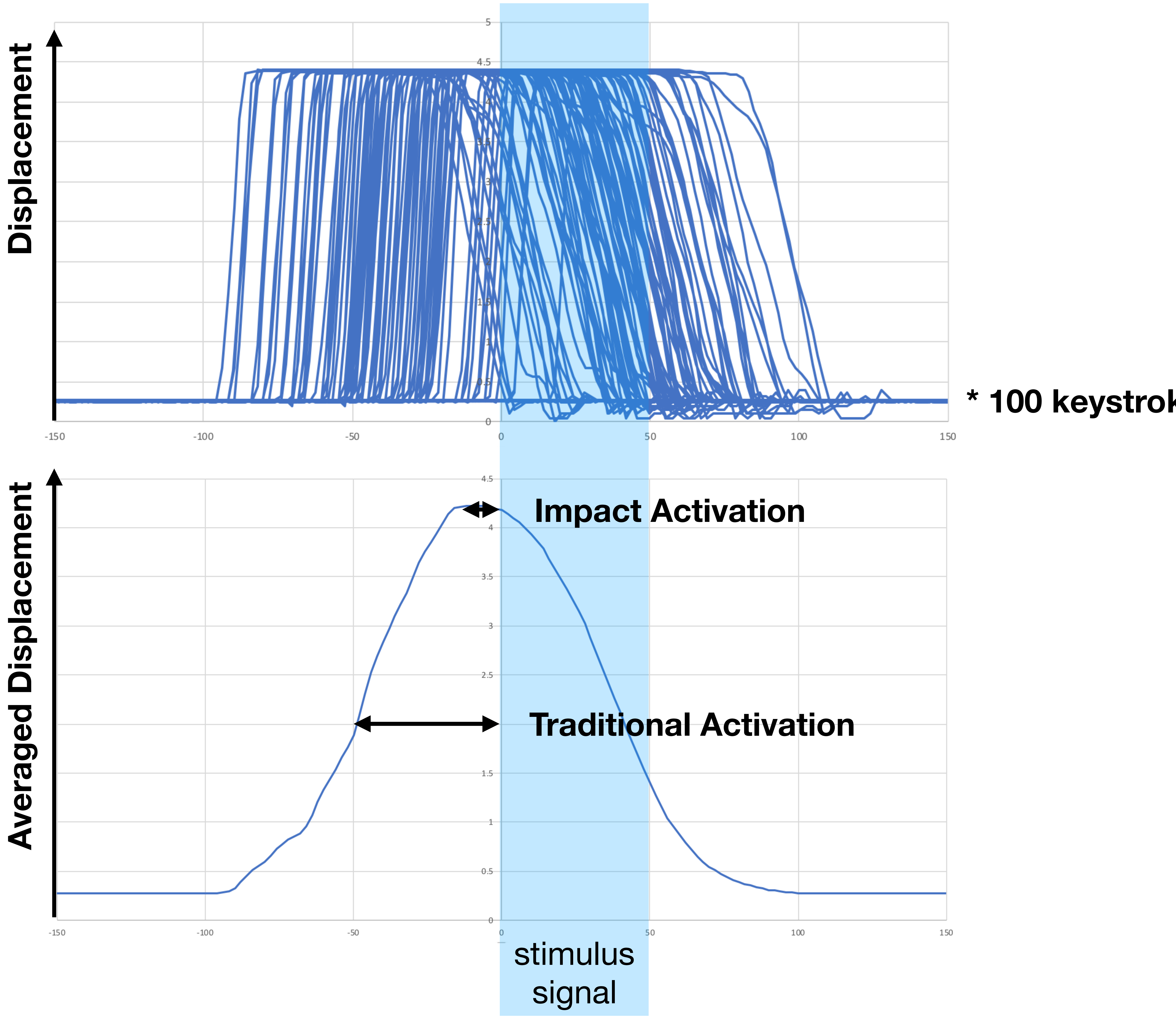


≈ **strength of mechanoreceptor stimulation**



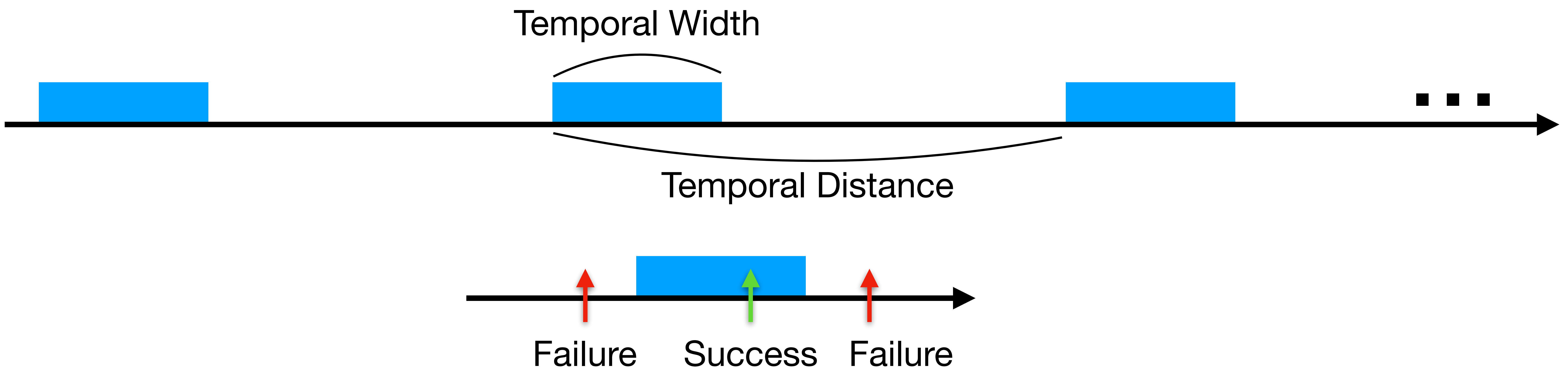
Kim, Sunjun, Byungjoo Lee, and Antti Oulasvirta. "Impact Activation Improves Rapid Button Pressing." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.
Oulasvirta, Antti, Sunjun Kim, and Byungjoo Lee. "Neuromechanics of a Button Press." *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 2018.

Empirical evidence



Lee, Byungjoo, and Antti Oulasvirta. "Modelling error rates in temporal pointing." *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 2016.

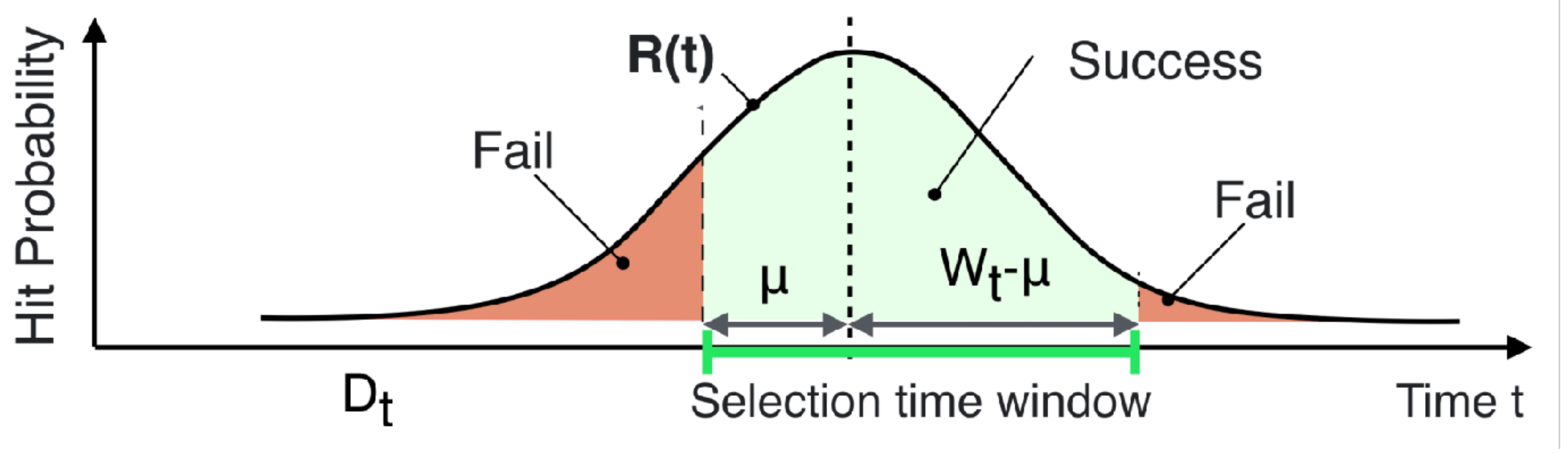
Task: Temporal Pointing



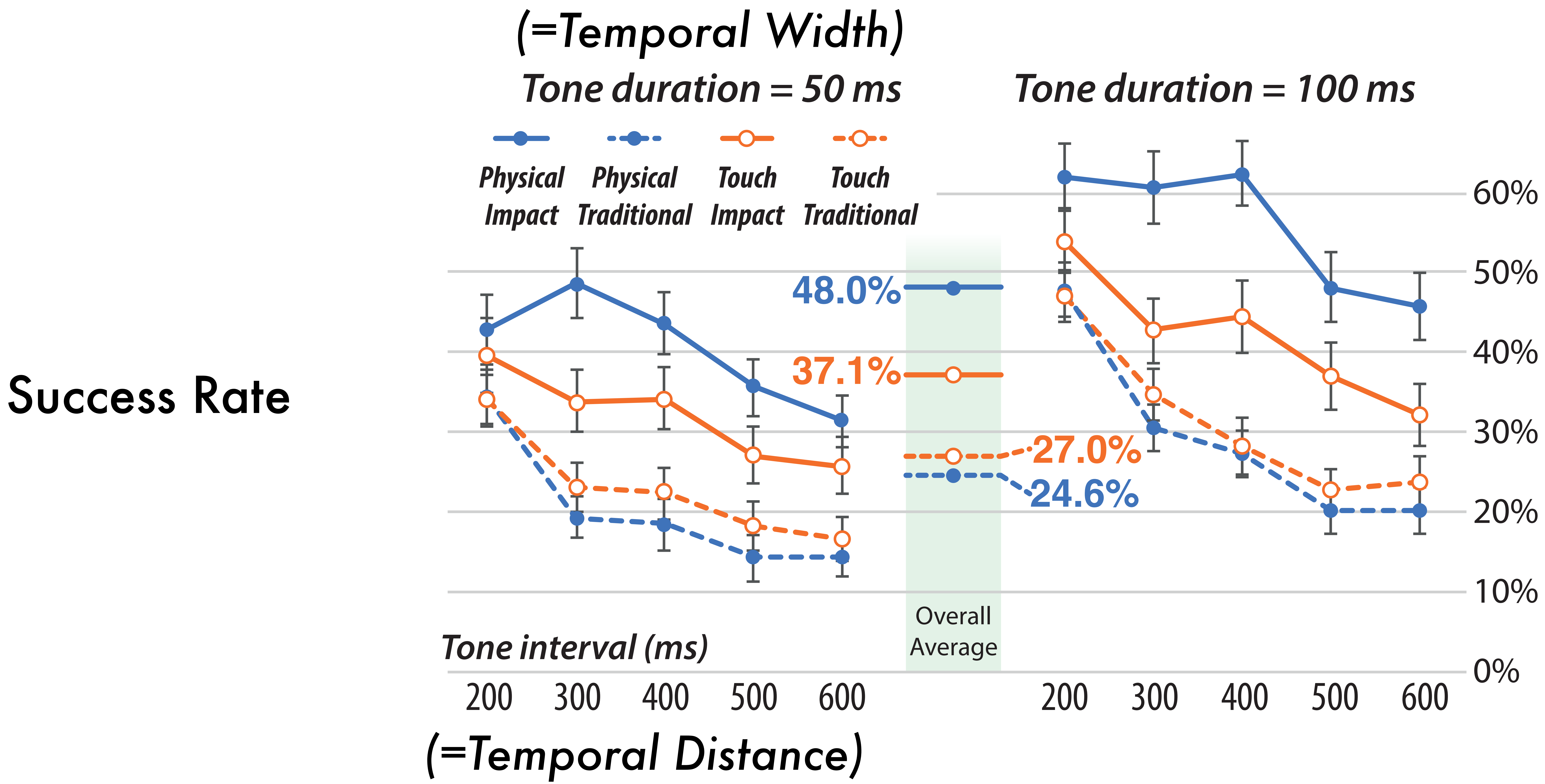
- An extension of Sensorimotor Synchronization task.
- Temporal version of Fitts' Law task:

$$ID_t = \log_2(D_t/W_t)$$

$$E(ID_t) = 1 - \frac{1}{2}\left[erf\left(\frac{(1-c_\mu)}{c_\sigma 2^{(ID_t+0.5)}}\right) + erf\left(\frac{c_\mu}{c_\sigma 2^{(ID_t+0.5)}}\right)\right]$$

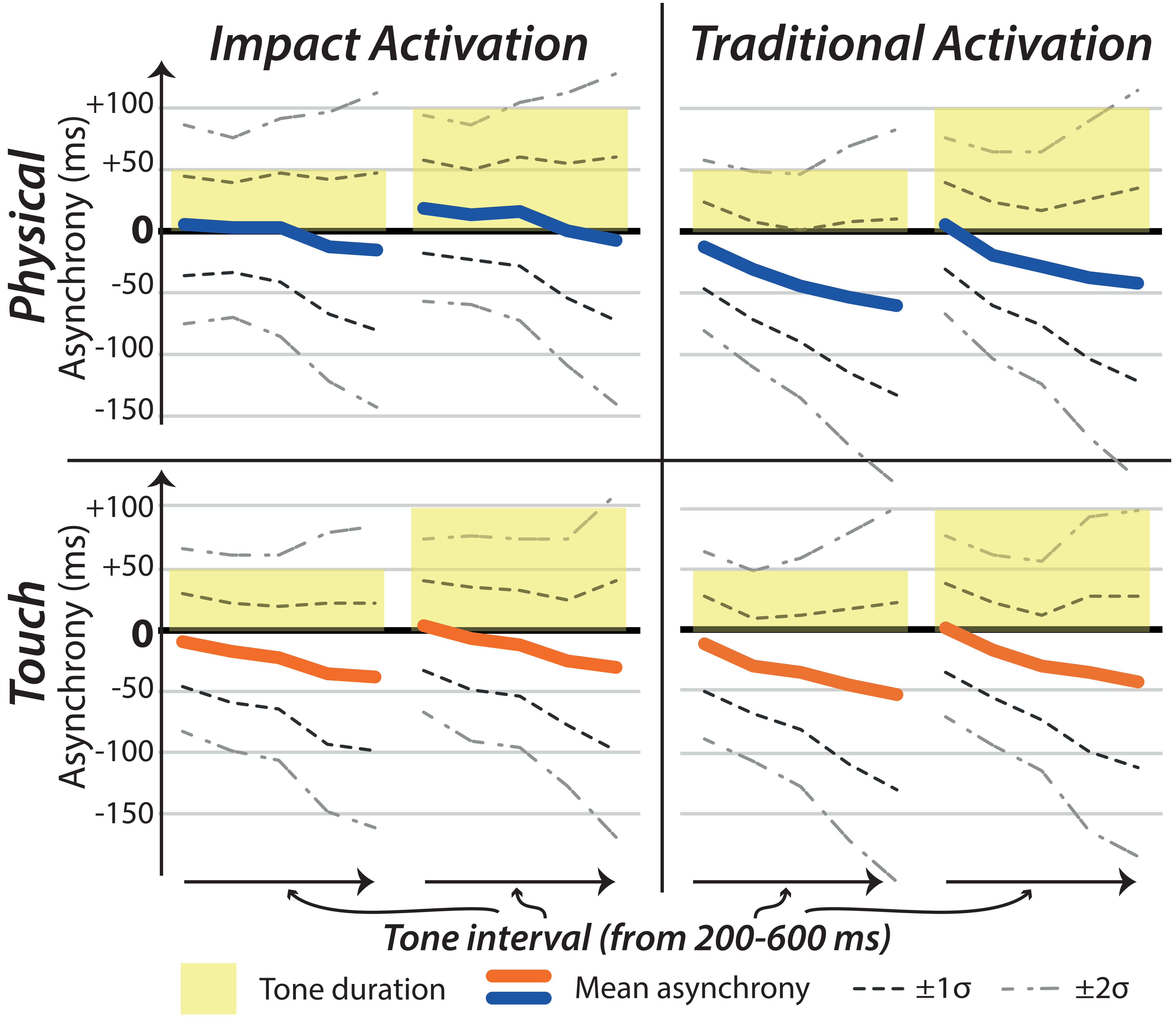


Traditional vs. Impact Activation



Traditional vs. Impact Activation

Asynchrony



Lecture 4:
Activation Point
3) Mid-air Button

A?
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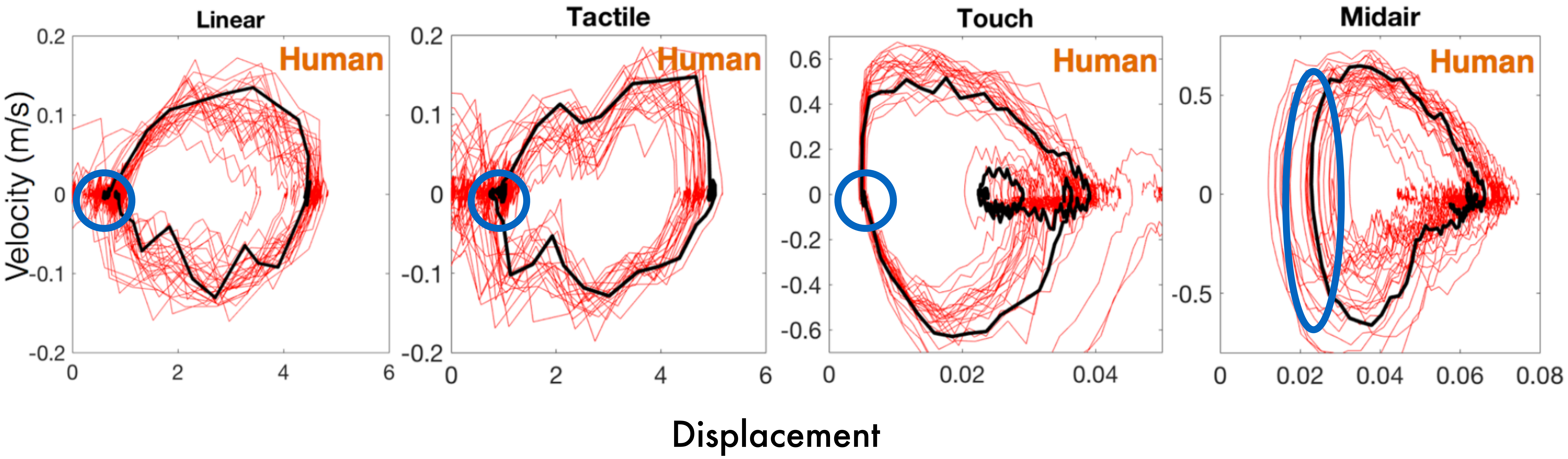
のこりボール 26
2
ヒット
BASEBALL RU
Wii
MIKI Yoshihito @ Flickr

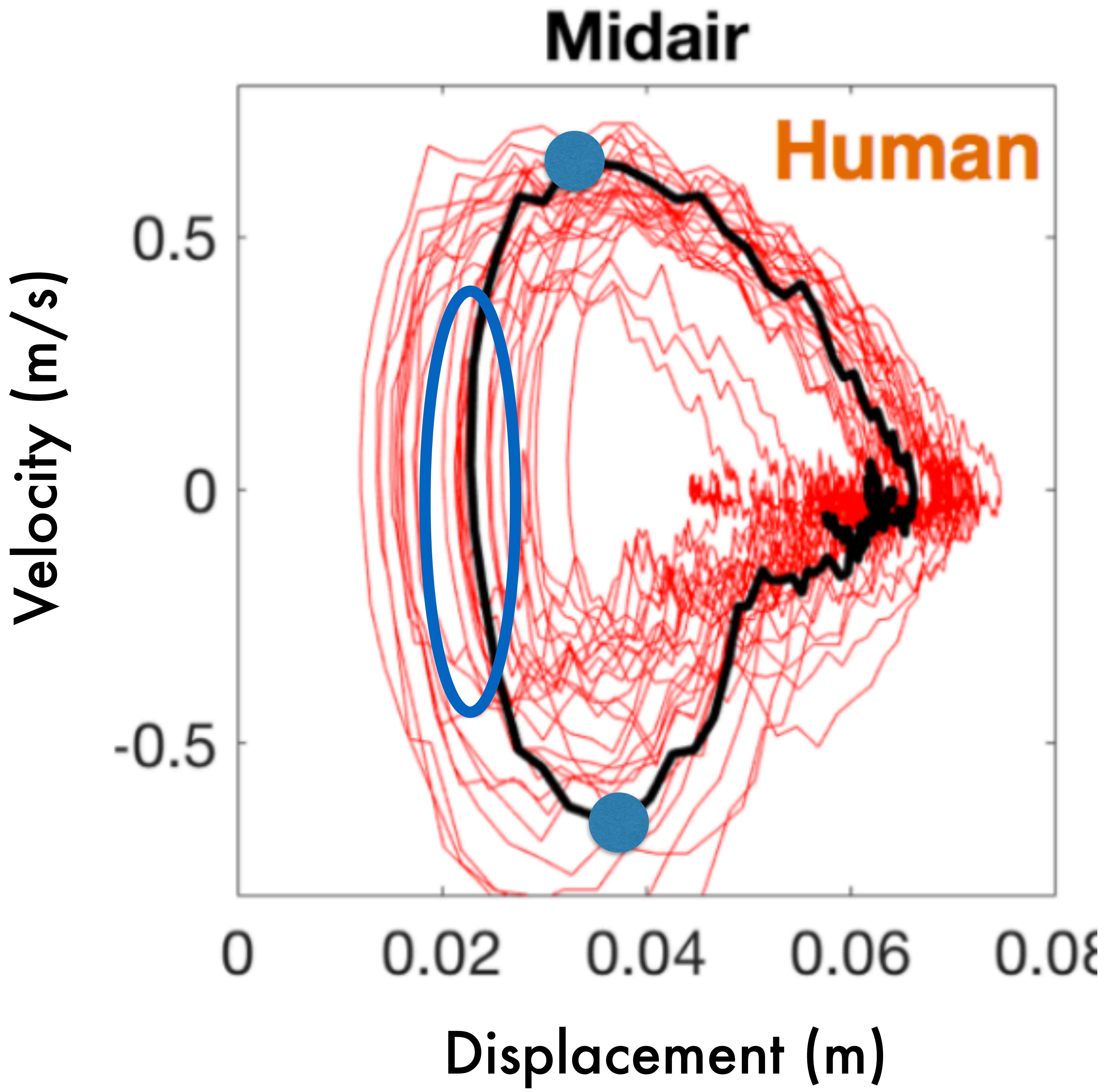
A?
Aalto University

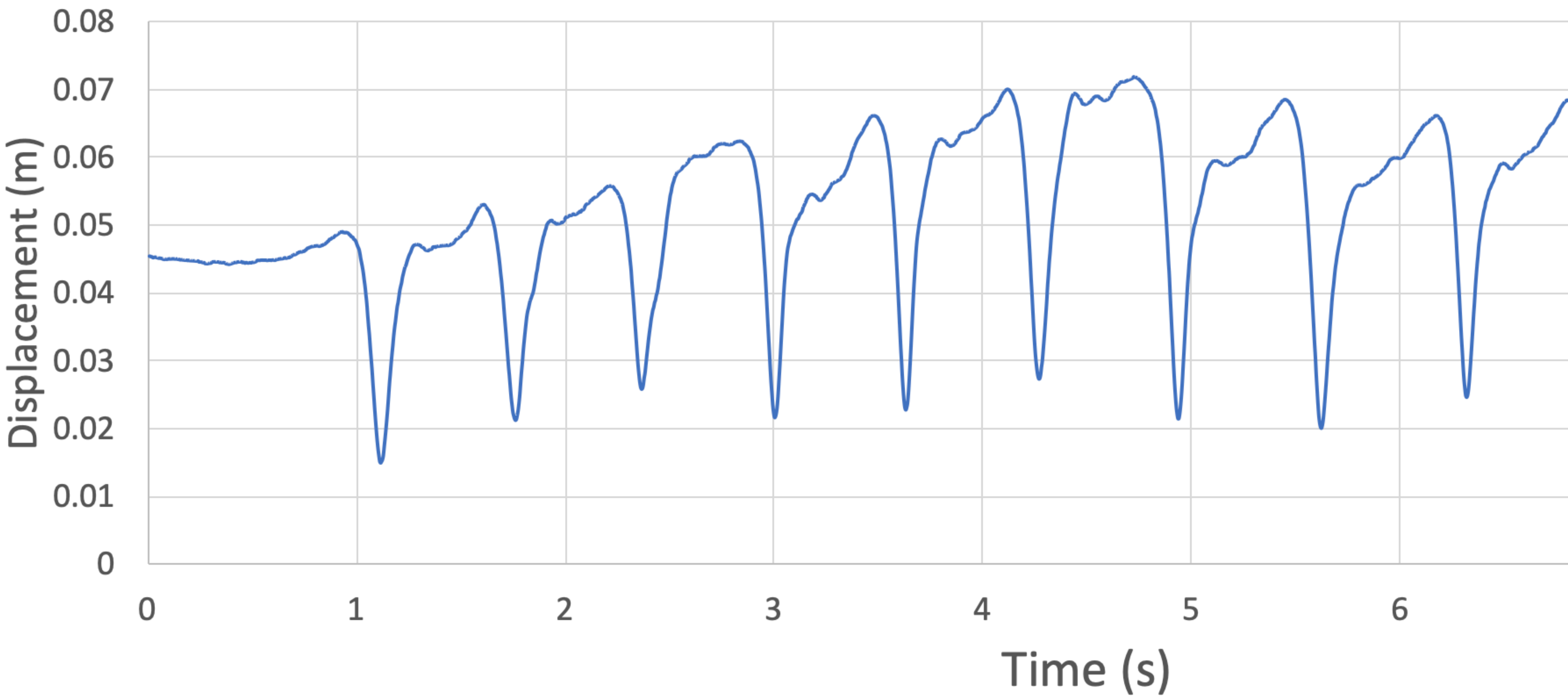
Challenge in Mid-Air Button



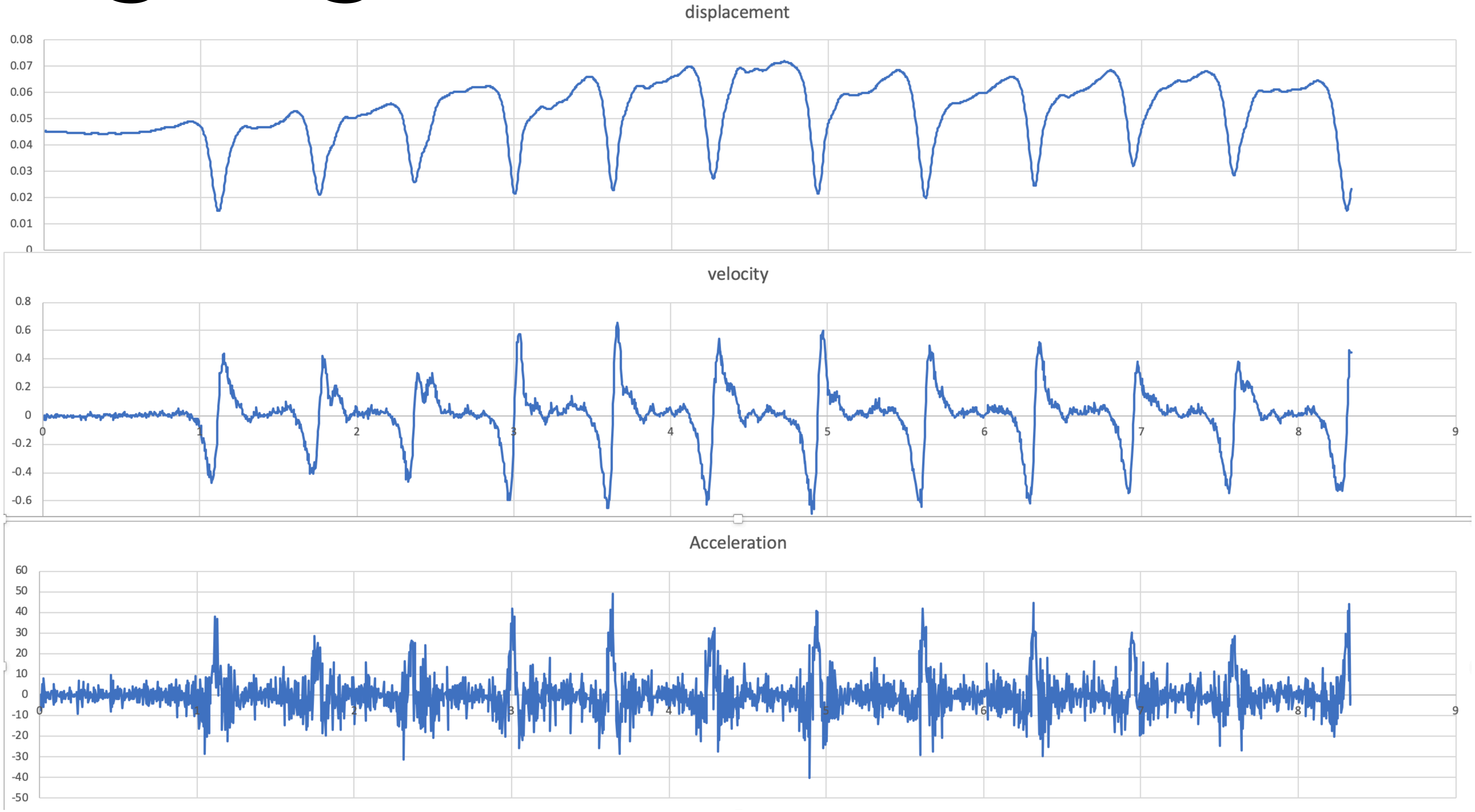
Lack of "impact"

Mid-air button motion profile





Designing mid-air button activation



Unified firmware (Arduino)

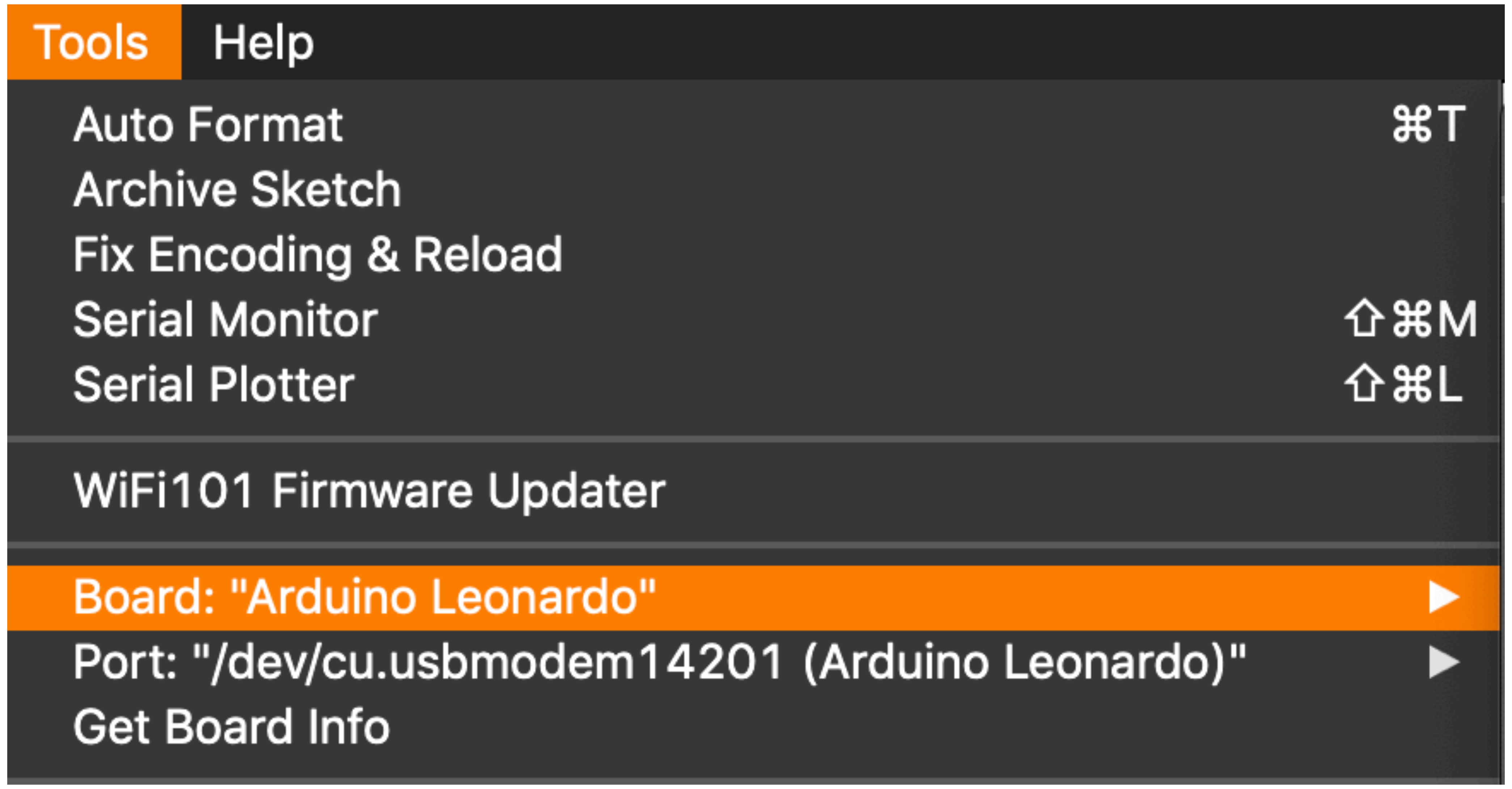
Open **/Programs/Arduino/MPU6050_DMP_KM/**

* Modified from https://github.com/jrowberg/i2cdevlib by Jeff Rowberg

Select **Tools → Board : Arduino Leonardo**

Select **Port → COM# (or /dev/cu.*) with (Arduino Leonardo)**

Upload



Minimal+Logger (Processing)

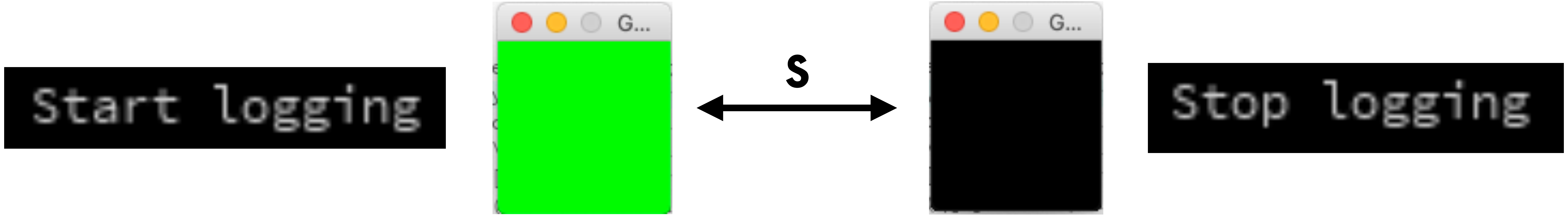
Open **Programs/Processing/GY_521_Minimal/**

* Modified from https://github.com/jrowberg/i2cdevlib by Jeff Rowberg

Run. (press **ESC** to escape)

* This sketch contains three examples: keyboard, mouse, gesture

press s (logging start / stop)



Using Logger

```
// logging example
printLog(acc[0]+","+acc[1]+","+acc[2]);
```

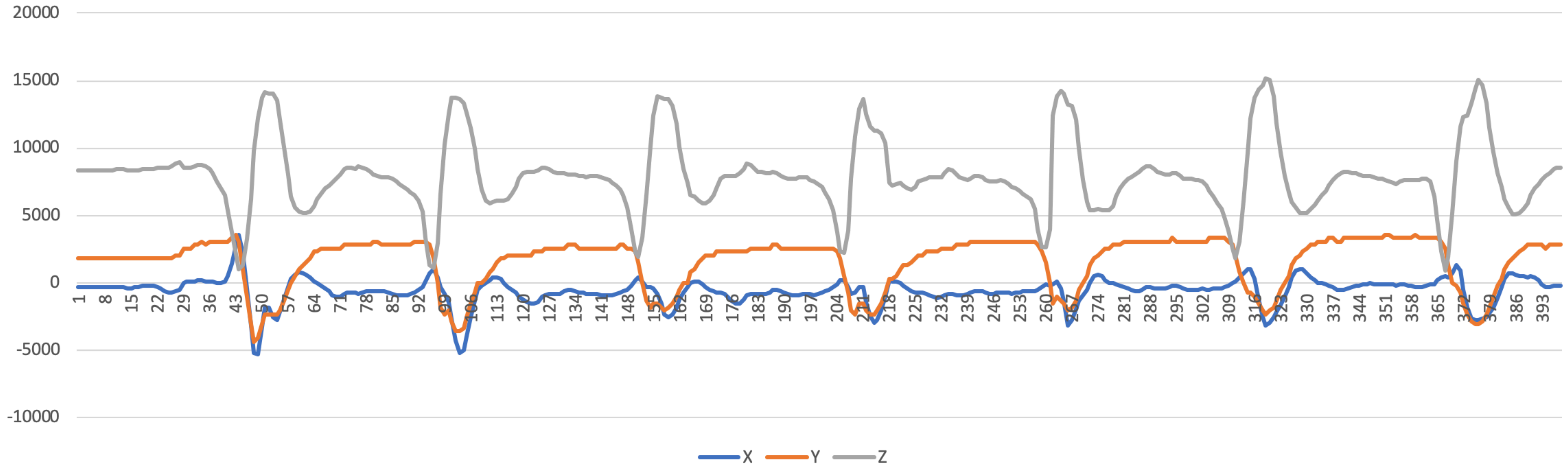
in the **processCommand()** function,

printLog("DATA YOU WAN TO LOG - SEPARATED BY COMMA");

➔ log will be saved to a .csv file.

Example log (accelerometer x, y, z)

Log recorded from periodic air-tappings

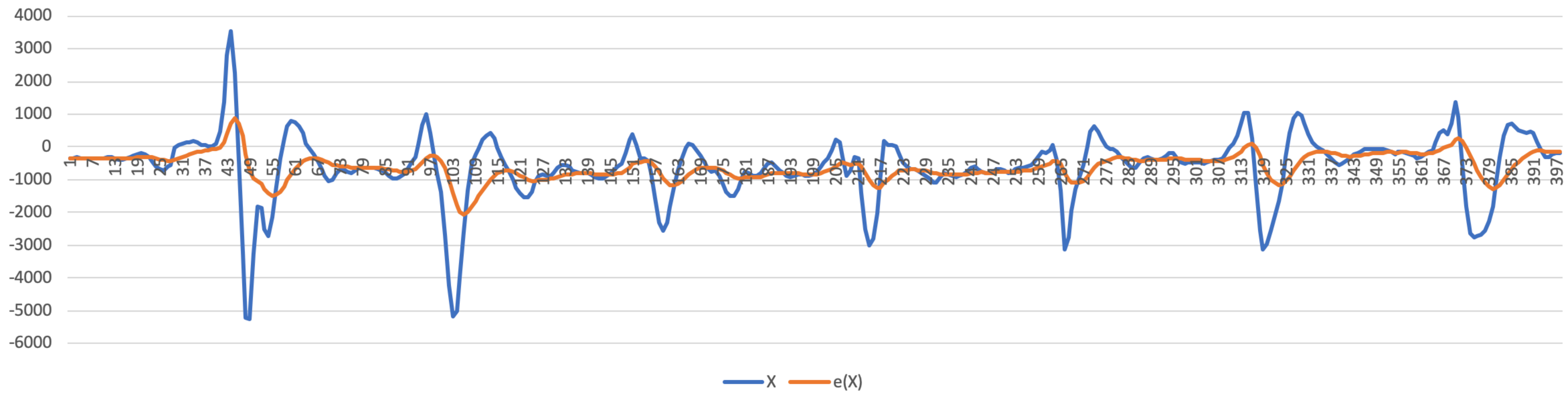


Air-tap detection

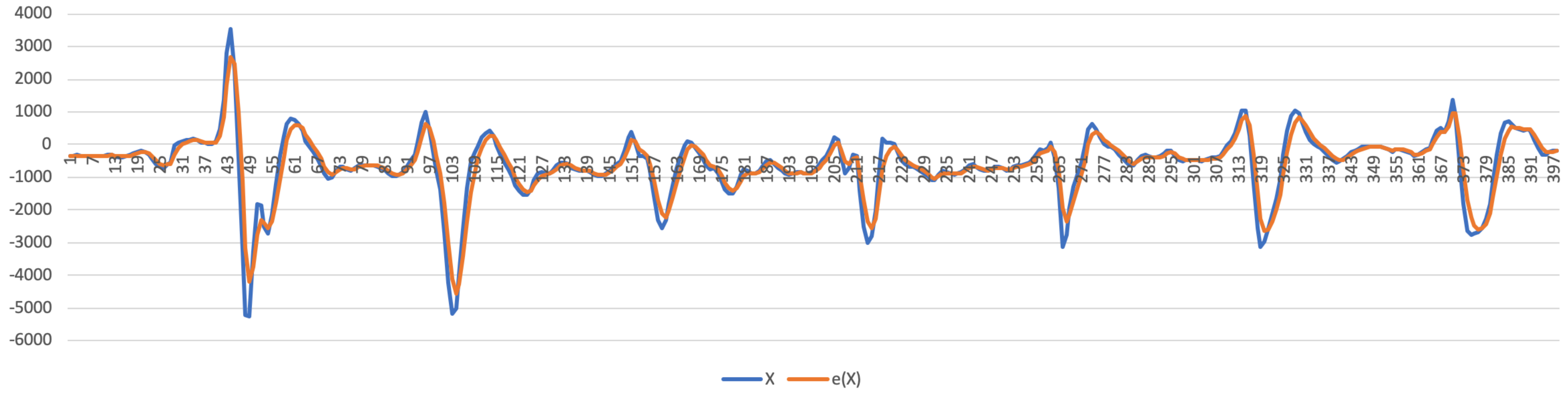
Objective: detection of max acceleration
Low-pass filtering: exponential filter

$s_0 = x_0$ $\qquad$ $s_t = \alpha x_t + (1 - \alpha) s_{t-1},\ t > 0$

$\alpha = 0.1$

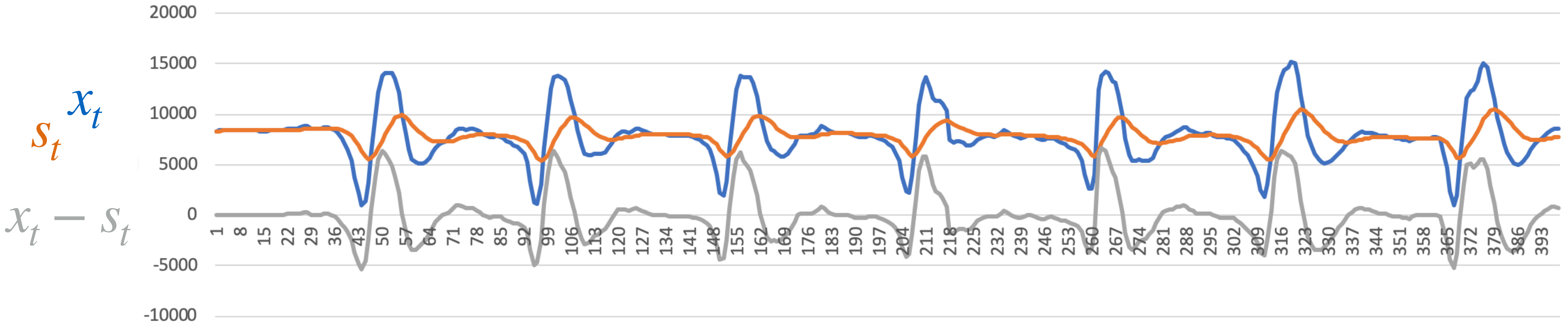


$\alpha = 0.0$



$$s_0 = x_0 \qquad s_t = \alpha x_t + (1-\alpha)s_{t-1},\ t > 0$$

Low-pass filter $= s_t$ **High-pass filter** $= x_t - s_t$



High-pass filter Acceleration calculation

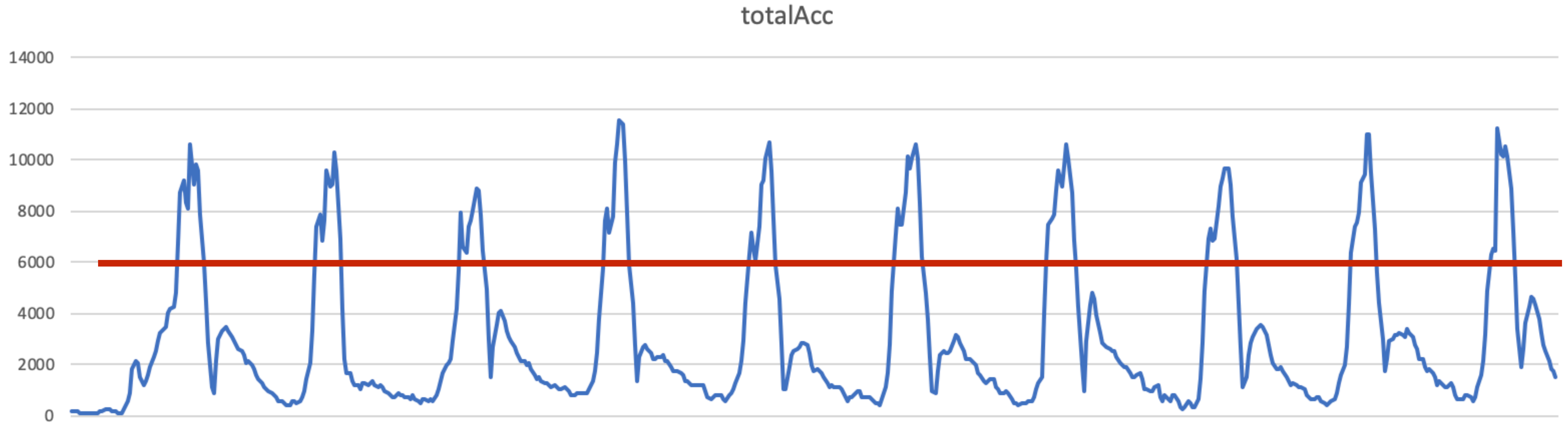
```
boolean isFirst = true;
float alpha = 0.1;
float ex=0;
float ey=0;
float ez=0;
boolean key_pressed = false;
```

```
if(isFirst) // s0 = x0
{
  isFirst = false;
  ex = acc[0]; ey = acc[1]; ez=acc[2];
}
else  // s_t = a*x_t + (1-a)*s_{t-1}
{
  ex = alpha * acc[0] + (1-alpha)*ex;
  ey = alpha * acc[1] + (1-alpha)*ey;
  ez = alpha * acc[2] + (1-alpha)*ez;

  // low-pass filter
  float lpf_x = acc[0]-ex;
  float lpf_y = acc[1]-ey;
  float lpf_z = acc[2]-ez;

  // vector lenght calculation
  float totalAcc = sqrt(lpf_x*lpf_x + lpf_y*lpf_y + lpf_z*lpf_z);

  printLog(acc[0]+","+acc[1]+","+acc[2]+","+totalAcc);

  if(totalAcc > 6000 && key_pressed == false)
  {
    key_pressed = true;
    press(CMD_RIGHT);
  }
  else if(totalAcc < 4000 && key_pressed == true)
  {
    key_pressed = false;
    release(CMD_RIGHT);
  }
}
```

Air-Tap detection

Raw signals

Calculated acceleration



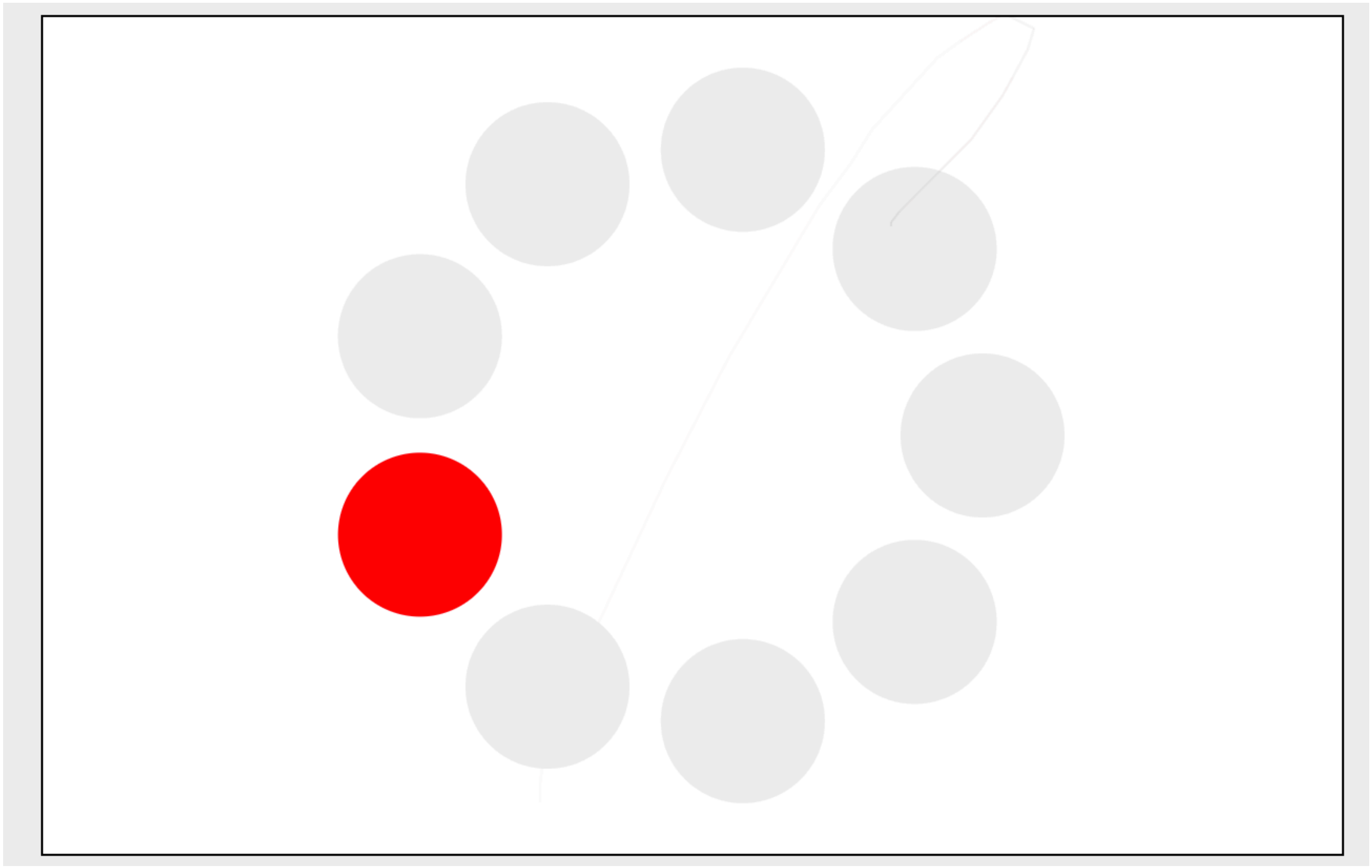
Project

Project Proposal Round 1

- Date: 18 Feb, 2019
- Material: IMU Sensor Module
- Goal: Design of Intelligent Input
  - Intelligent input means; the behavior of the device changes to be optimized over time.
- Requirement for the next presentation
  - Set a target application (or task) and identify the required input commands.
  - Design the mapping between motion and commands.
  - Set a calculable objective function.

Example

- Mouse optimization for Fitts' Law test
- Parameter: gain function ***g***
- Objective (=cost) function ***f(g)*** = throughput
- Optimization goal: ***argmax(f(g))***



Example

- Keyboard optimization for SMS task
- Parameter: input registration threshold ***x***
- Objective (=cost) function ***f(x)*** = SD of ITI
- Optimization goal: ***argmin(f(x))***