Visualizing Multimodal Data

LOT Winter School 2024, Šárka Kadavá

Content of the workshop

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Why should we care?

02

What is possible?

03

Plots for multimodal data

04

Dashboards

01

Why should we care?

Imagine...

You spend hours and hours on **designing** an experiment, **piloting** the setup, **recording** the data...

You are done, and you start to process the data – **extract** features, **explore** their relationships, building **statistical** models, etc.

And when you are finaly done...

IS GESTURE-SPEECH PHYSICS AT WORK IN RHYTHMIC POINTING? EVIDENCE FROM POLISH COUNTING-OUT RHYMES

Šárka Kadavá[1,3,*], Aleksandra Ćwiek[1], Katarzyna Stoltmann[2], Susanne Fuchs[1], Wim Pouw[3]

[1]Leibniz Center General Linguistics, Berlin, Germany [2]adesso SE, Berlin, Germany [3]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, Netherlands
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ABSTRACT

'Gesture-speech physics' refers to a possible biomechanical coupling between manual gesture and speech. According to this thesis, rapid gesturing leaves a direct imprint on acoustics (intensity, F0), as gesture accelerations/decelerations increase expiratory forces and therefore subglottal pressure, leading to higher amplitude envelope peaks and higher F0 values. This acoustic effect has been reported in lab experiments, spontaneous speech, clinical studies, and professional vocal performers. The current study investigates this phenomenon in Polish counting-out rhymes, using motion capture data and acoustic recordings from 11 native Polish speakers. Following the gesture-speech physics thesis, we expect acceleration/deceleration peaks to be correlated with speech intensity/F0. Through Bayesian analyses, we obtained a weak but reliable coupling of deceleration of the pointing hand and the nearest peak in the smoothed amplitude envelope.

Keywords: pointing gestures, motion tracking, poetry, prosody, coupling

1. INTRODUCTION

The evidence that gesture-speech coordination on the prosodic level arises out of basic properties of physiology and motor control is increasing [1, 2, 3, 4, 5, 6]. This contrasts with the argument that gesture is a sophisticated cognitive achievement, proliferating due to cultural conventionalization [7].

While not downplaying either of those constraints, according to the gesture-speech physics account (see [6]), there is a biomechanical nudge for aligning peaks in F0 and amplitude envelope with the peak of the physical impulse. As such, the human voice receives an 'imprint' due to the gestural activation of expiration-related muscles. Specifically, upper limb acceleration and deceleration affect rib-cage movement and thus subglottal pressure. That [unclear] studies, showing that neural networks trained on acoustics and body kinematics can come to predict the presence of gesture or kinematic properties of gestures [8, 9, 10].

Although gesture-speech physics seems robust in some tasks, a recent study on leg and arm biking suggests that acceleration may need to reach a certain threshold to affect speech acoustics [11]. This is in line with previous research showing that body parts with lower mass (hand vs. arm) have much weaker effects on speech (e.g., [12]), if at all [13].

The reason why the biomechanical gesture-speech coupling is weak is likely because there must remain the flexibility to speak in certain ways when gesturing. The larynx should indeed be flexible to resist the effect of motion at times it is appropriate to do so. After all, the primary function of the larynx is to act quickly and protect the lungs from inhaling foreign bodies [14].

This study replicates the basic kinematic-acoustic coupling findings from previous research. Our dataset consists of motion data recorded while performing Polish counting-out rhymes involving pointing movement. During a counting-out rhyme game, one person speaks a rhyme while rhythmically moving their index finger between themselves and another person. Having clear turning points, these childhood poems are a valid paradigm to investigate speech-gesture physics, as appreciated by previous studies [15].

We extend previous work by studying forward and backward pointing movement and speech rate as additional factors. So far, only flexion-extension movements have been studied [16] and it is possible that different movements will have different respiratory interactions. Looking at a faster rate is motivated by the fact that this may go hand in hand with larger accelerations/forces. However, the rate may also change the complexity of gesture-speech physics, as different coupling strengths and [unclear] stiffness are involved.

Model	Parameter	Estimate [95% CrI]	$Pr(\beta < or > 0)$
F0 acc	Intercept	185.58[172.59;198.94]	
	Speech rate	8.16[1.70;14.51]	0.99
	Sex	104.07[77.81;129.97]	1.00
F0 dec	Intercept	177.12[162.24;191.94]	
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	Wrist dec. peak	−0.02[−0.04;−0.00]	0.99

Table 1: The table lists out all intercepts, as well as the parameters with a reliable effect on the outcome variables of the four models, with posterior means and the 95% CrI. The rightmost column is the posterior probability of the effect to be below or above 0, depending on the direction.

on amplitude deceleration peak is not reliable, however, since the task was not heavily controlled, we acknowledge that those relationships should be further studied in the future. As can be seen in Figure 2, the main effect of *wrist deceleration peak* on the amplitude envelope peak we reported above differs when it is within backward vs. forward movement. Nevertheless, given the priors, the data, and the model, there was no interaction effect of the two parameters ($\beta = -0.00[-0.02;0.01]$).

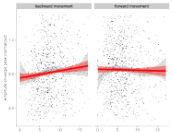

Figure 2: The linear relationship between deceleration peak and amplitude envelope peak. Dashed non-linear 'loess' line reflects possible non-linearities. Note that the deceleration values have been absolutized.

4. DISCUSSION

The current study goes beyond previous research on gesture-speech physics by assessing statistical coupling in (1) multi-directional (2) pointing movements in (3) the Polish language. Our findings suggest that deceleration peaks scale to their nearest amplitude envelope peak, rather than F0. This [unclear] envelope or F0 peaks.

Why did the rapidity by which participants halted a pointing movement (i.e., deceleration) not scale to the nearest F0 peak? The gesture-speech physics thesis proposes that there is a mechanical interaction between an upper limb and the body during acceleration or deceleration. The physical impulse of a upper-limb movement produces a mechanical loading onto the rib cage, which limits its movement and impacts subglottal pressures necessary for voice production. Subglottal pressures are primarily linked with affecting intensity, and only secondarily F0, which is under more flexible laryngeal control.

That there is a coupling of deceleration rather than acceleration might look like a counterargument for gesture-speech physics. However, comparing the absolute raw values of deceleration and acceleration peaks, we found 20% lower magnitudes for acceleration than deceleration. In line with [11], we suppose that a certain threshold needs to be reached before a significant effect of physics arises.

As for the deceleration effect alone, it is known that speakers coordinate their emphasis in speech with the moment when the limb movement reaches its destination [27]. Thus, emphasis is generally not located at the initial stage of pointing; rather, it occurs when reaching the intended target.

Further, we did not find that kinematic peaks affected speech differently depending on the direction of movement. This means forward and backward movements along the sagittal plane likely perturb vocalization by increasing subglottal pressure, much like flexion-extension movements along the frontal plane [16].

For future research, potential alternative hypotheses should be investigated. For example, other kinematic variables (e.g., speed) need to be assessed for speech coupling. Our study is also limited in the number of participants, cautioning generalizability, but it has a large number of trials and events that have been analyzed, increasing the reliability of the reported effects within our sample. Moreover, since we do not directly measure muscle activity in relation to respiratory-vocal states, it is always possible to maintain that the current kinematic-acoustic effect is solely a neurally controlled achievement. Such an explanation requires an auxiliary hypothesis about why the brain would monitor acceleration peaks and couple them to vocalization. While we deem it possible that the brain is tuned like this, it would be precisely because there is a weak biomechanical coupling to [unclear]

And when you are finaly done...

28. Multimodal Phonetics ID: 955

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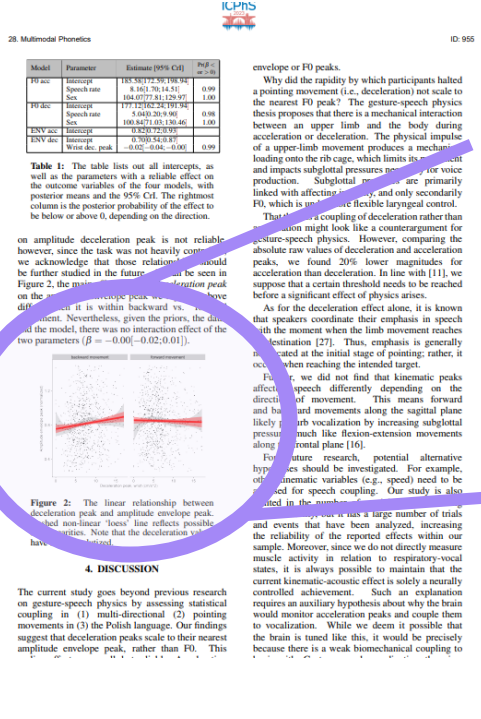

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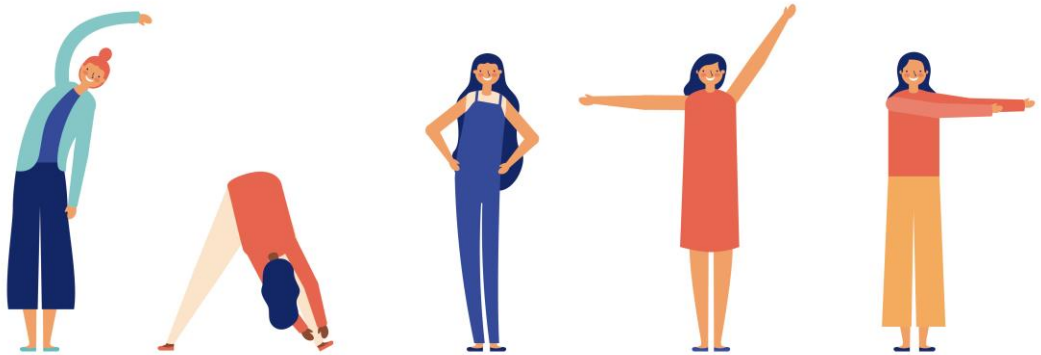
…this is what remains from my beautiful data

Where are the videos that took so much time to collect?

Where is the movement that we claim to be so important?



02

What is possible?

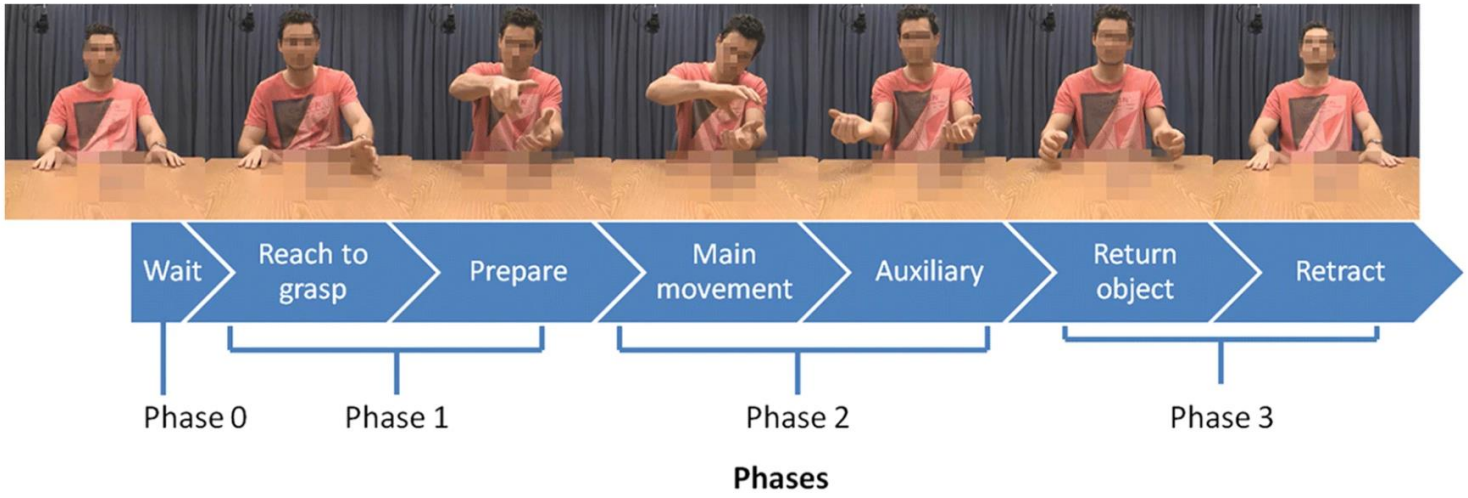
Imagine...

You have an experiment in which people do some movements and sounds. Now you are writing a paper...

How do you make use of these data?

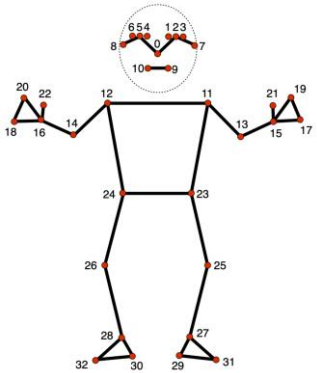
Example

(Trujillo et al., 2020)

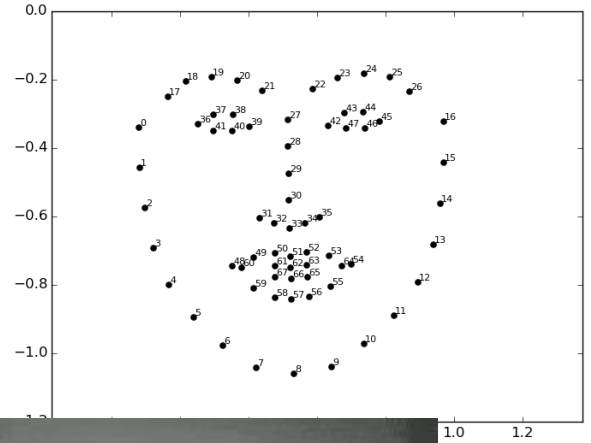


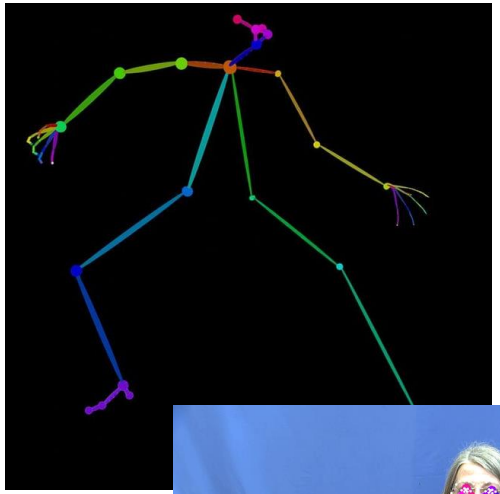
Examples

MediaPipe

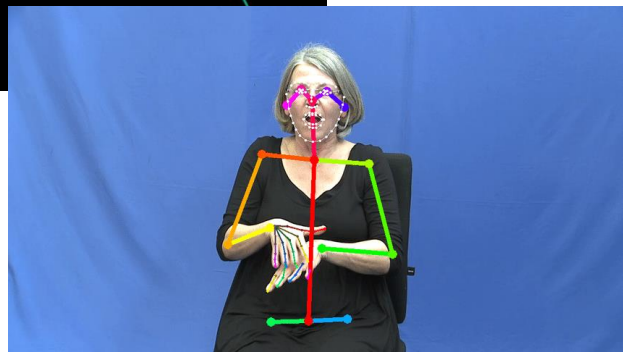


OpenFace

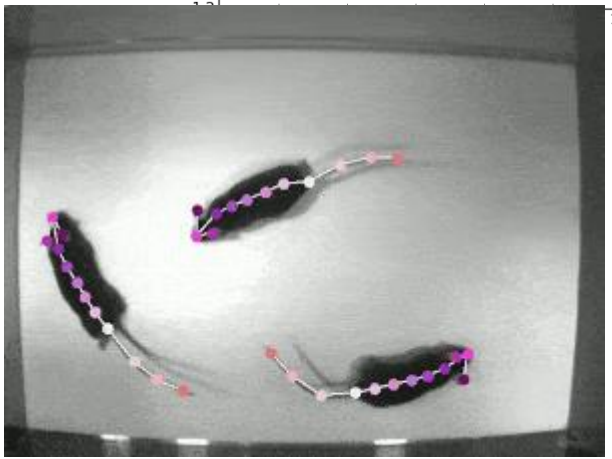




OpenPose



Schulder & Hanke, 2020



DeepLabCut

Example

(Pouw et al., 2023)

https://tsg-131-174-75-200.hosting.ru.nl/siamang/

03

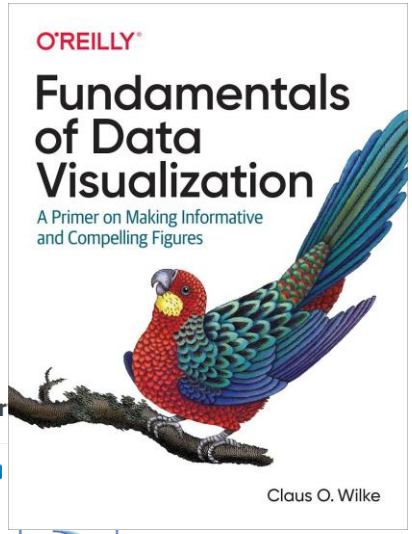
Plots for multimodal data

Friends Don't Let Friends Make Bad Graphs

DOI 10.5281/zenodo.7542491

Friends don't let friends make certain types of data visualization - What are they and why are they bad.

- Author: Chenxin Li, postdoctoral associate at Center for Applied Genetic Technologies, University of Georgia.
- Contact: Chenxin.Li@uga.edu | @ChenxinLi2



Charming Data

@CharmingData · 37.3K subscribers · 170 videos

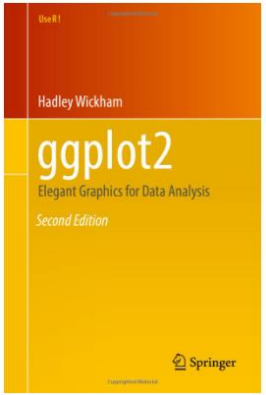
Charming Data is a Community of people inspired to make positive

github.com/Coding-with-Adam/Dash-by-Plotly and 2 more links

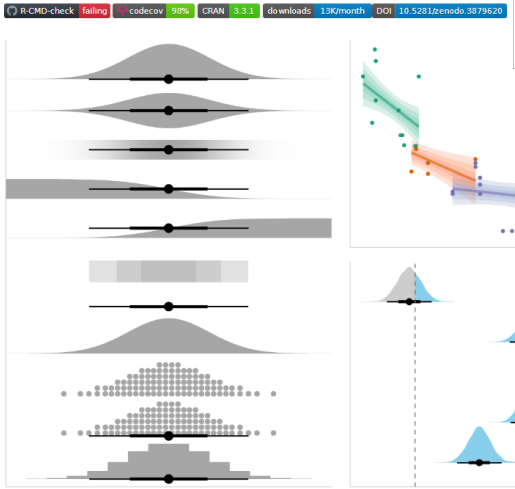
Subscribed Join

plotly

https://dash.plotly.com/



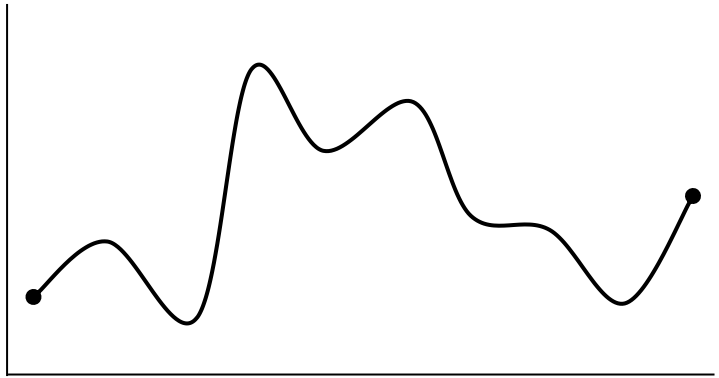
ggdist: Visualizations of distributions and uncer



Multimodal essentials

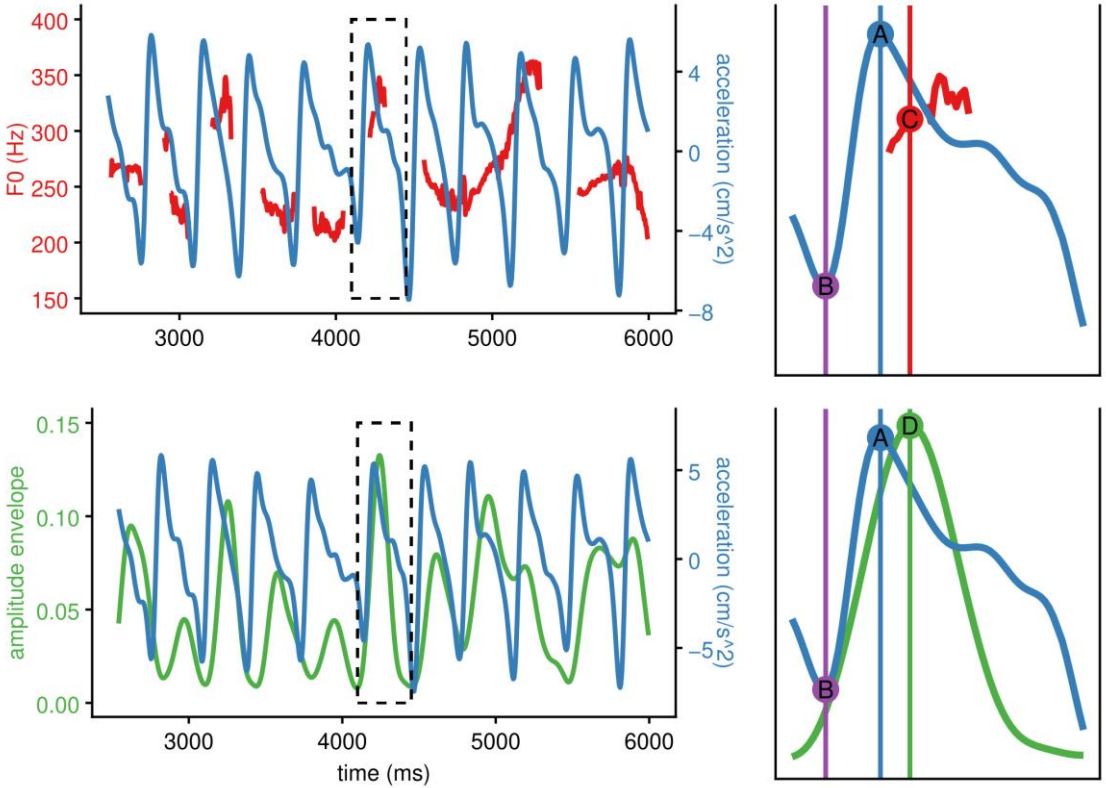
Our data

- change **in time**
- consists of **various signals**
- that have **variety of characteristics**



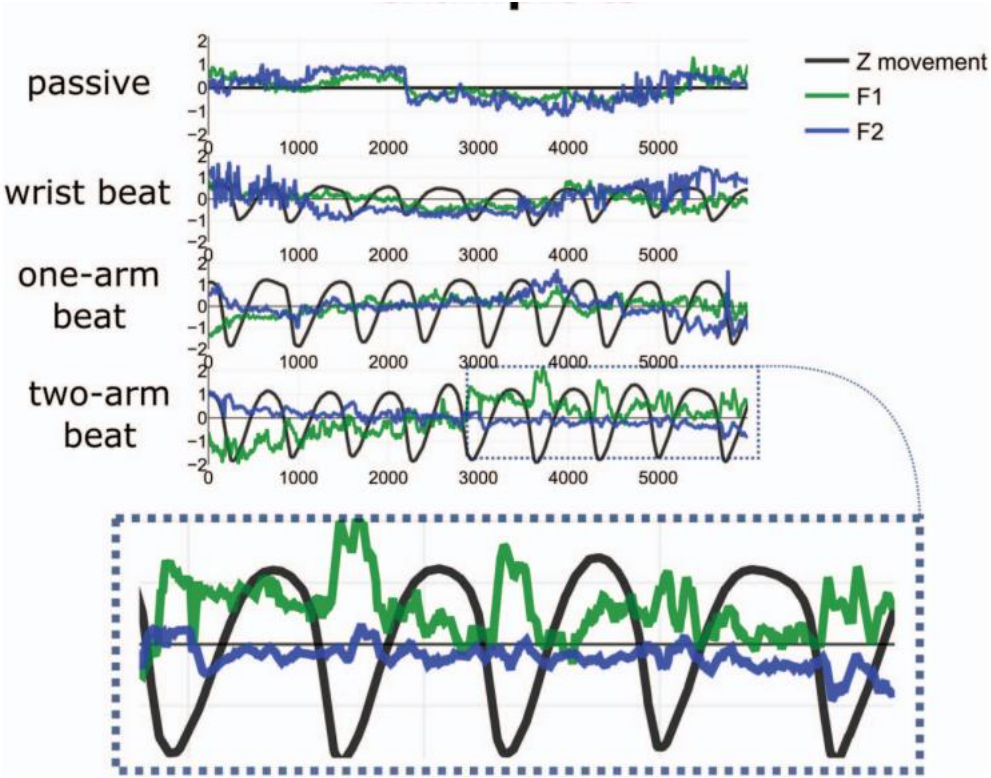
Example

(Kadavá et al., 2023)



Example

(Pouw et al., 2020)

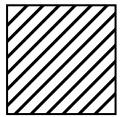


04
Dashboards

Dashboards

App that allows **user** to display various types of **(visual) data**

→ it provides **direct access** to our (visual) data
→ it has a default interface, but also user freedom



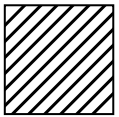
Key components

Data

Html/dash components

Default interface

Update



Let’s get to work

Last but not least

You need to upload the app to server
to be able to use it online

Last but not least

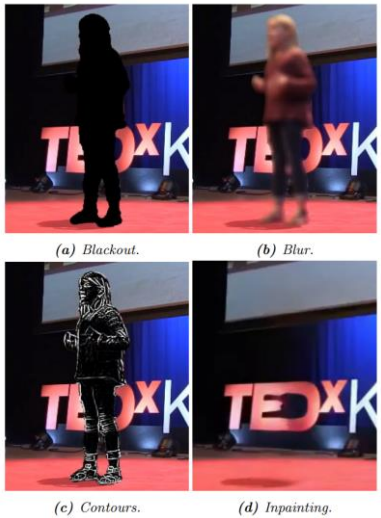
Be aware of privacy!

Masking tools

MaskAnyone

rohansaw / **Privacy4MultimodalAnalysis**

(a) Original. *(b) Olaf Scholz.*



(a) Blackout. *(b) Blur.*

(c) Contours. *(d) Inpainting.*

Masked-Piper **(Owoyele et al., 2022)**

Thank you

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sarkadava

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