Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

75 NRP
Big Data
National Research Programme

PhoneMD:
Learning to Diagnose Parkinson's Disease from Smartphone Data

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ETH Zurich


ALI
REZNICK Productions

Parkinson's Disease (PD)

- Slow **degeneration of motor skills**
- **Hard to diagnose**
    - Assessment of **symptoms**
        - **Similar** symptoms in other diseases
        - Symptom **fluctuations**
- Only ~80% of diagnoses are accurate[1]
- **~7m (0.3%)** affected, **120,000** deaths[2]

[1] Rizzo, G. et al. (2016) *Accuracy of clinical diagnosis of Parkinson disease: A systematic review and meta-analysis.* Neurology 86 (6).

[2] de Lau, LM and Breteler MM. (2006) *Epidemiology of Parkinson's disease.* Lancet Neurology 5 (6).

Wide Variety of Symptoms

Cognition

Speech

Dexterity

Movement

Motor Impairments

Tilted Posture

Rigidity

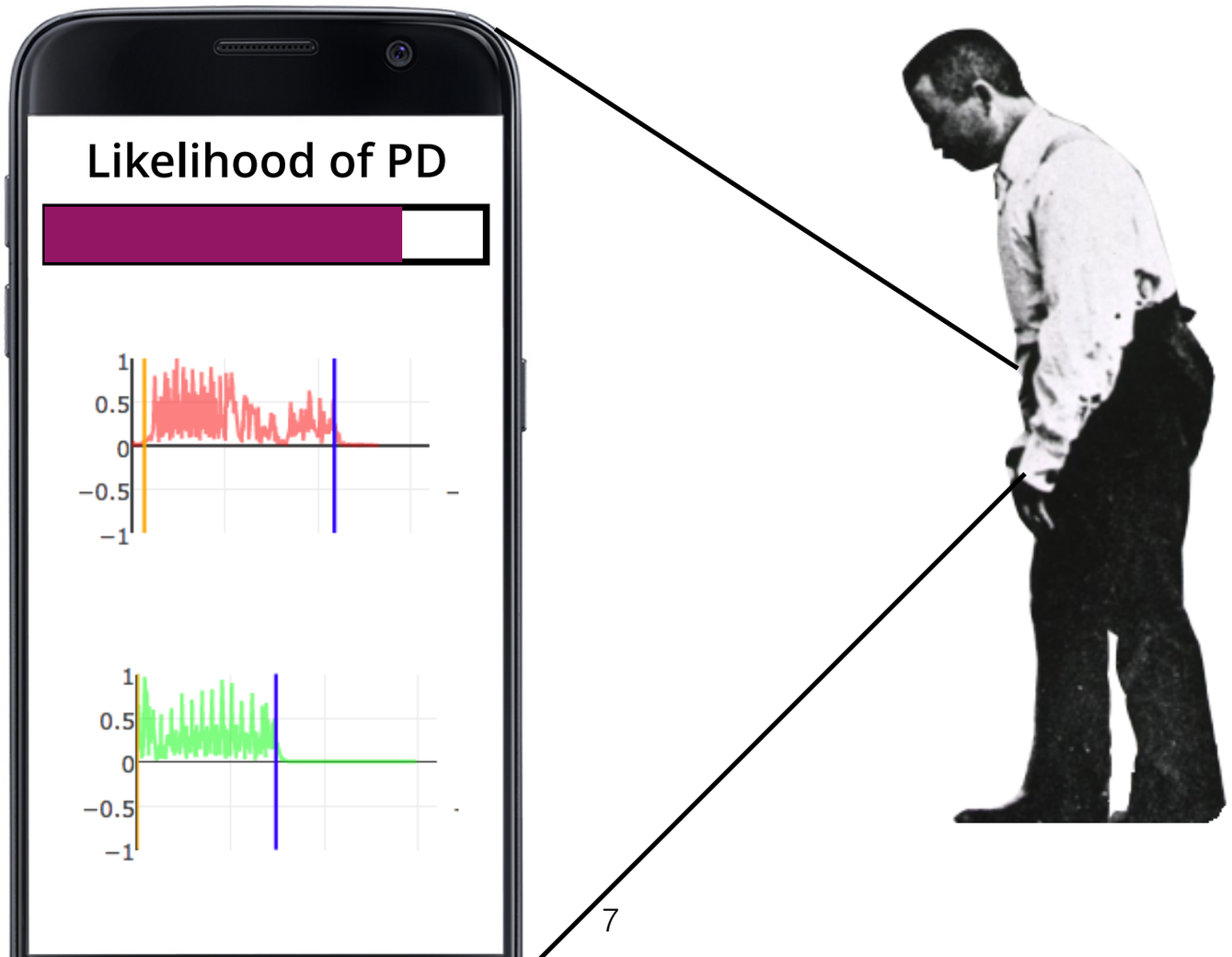
Reduced Arm Movement

Tremor of Extremities

Shuffling Gait & Short Steps

The Idea

Can we use machine learning on long-term smartphone data to diagnose Parkinson's?



The Dataset

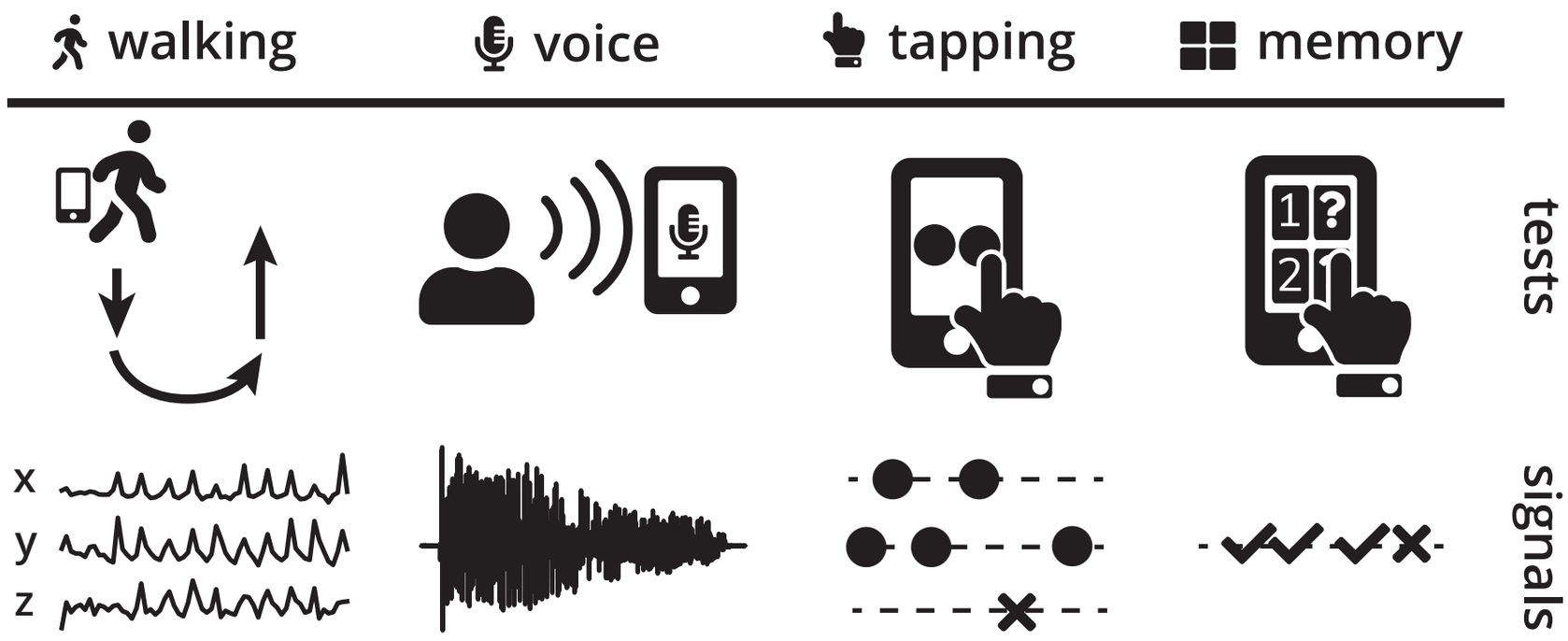
The mPower Study

- We use data collected in the **mPower study**[1]
    - Openly available on **Synapse**[2]
- App users (with and without Parkinson's, n=1853) were asked to perform several tests regularly
    - Outcome: **Prior clinical PD diagnosis**

[1] Bot, B.M., et al. (2016) *The mPower study, Parkinson disease mobile data collected using ResearchKit.* Scientific data 3.

[2] Synapse Platform, https://www.synapse.org/#!Synapse:syn8717496 (Accessed: Nov 13, 2017)

Tests Overview



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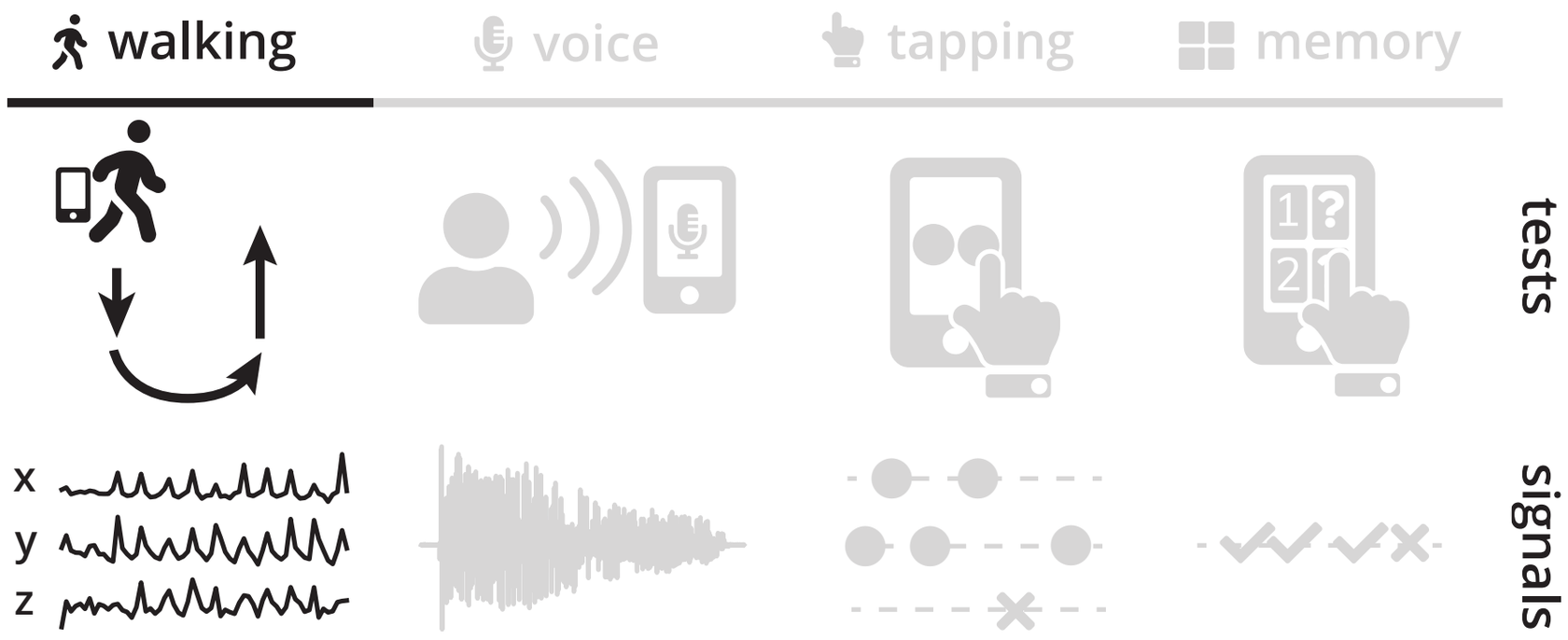

mPower Walking Test

- In the walking task, participants were asked to do the following three-segment task (each ~30s):

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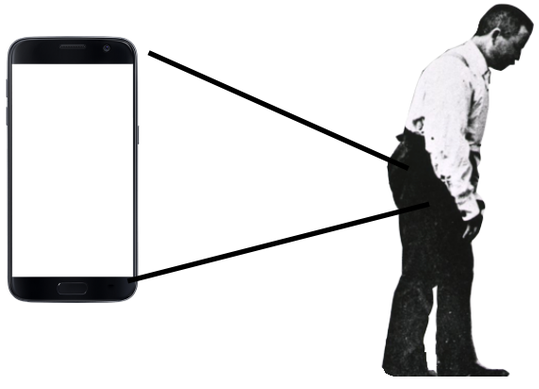

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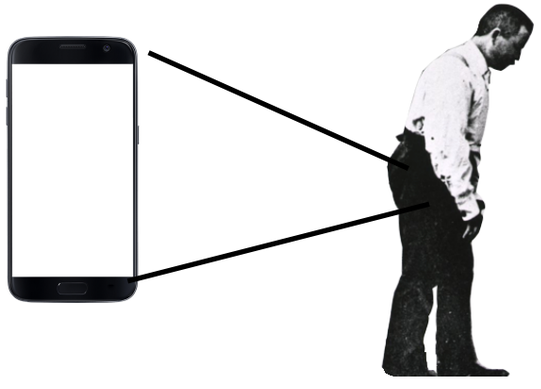
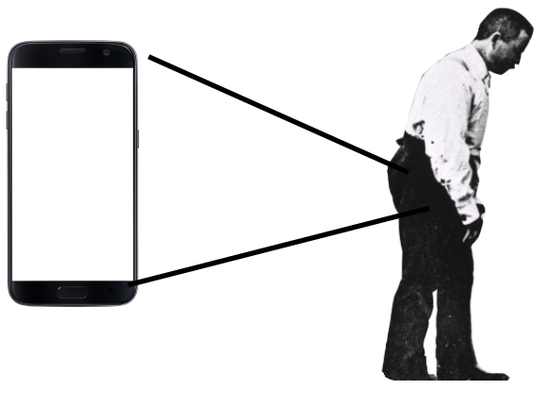


(1) Walk outbound

mPower Walking Test

- In the walking task, participants were asked to do the following three-segment task (each ~30s):

(2) Rest



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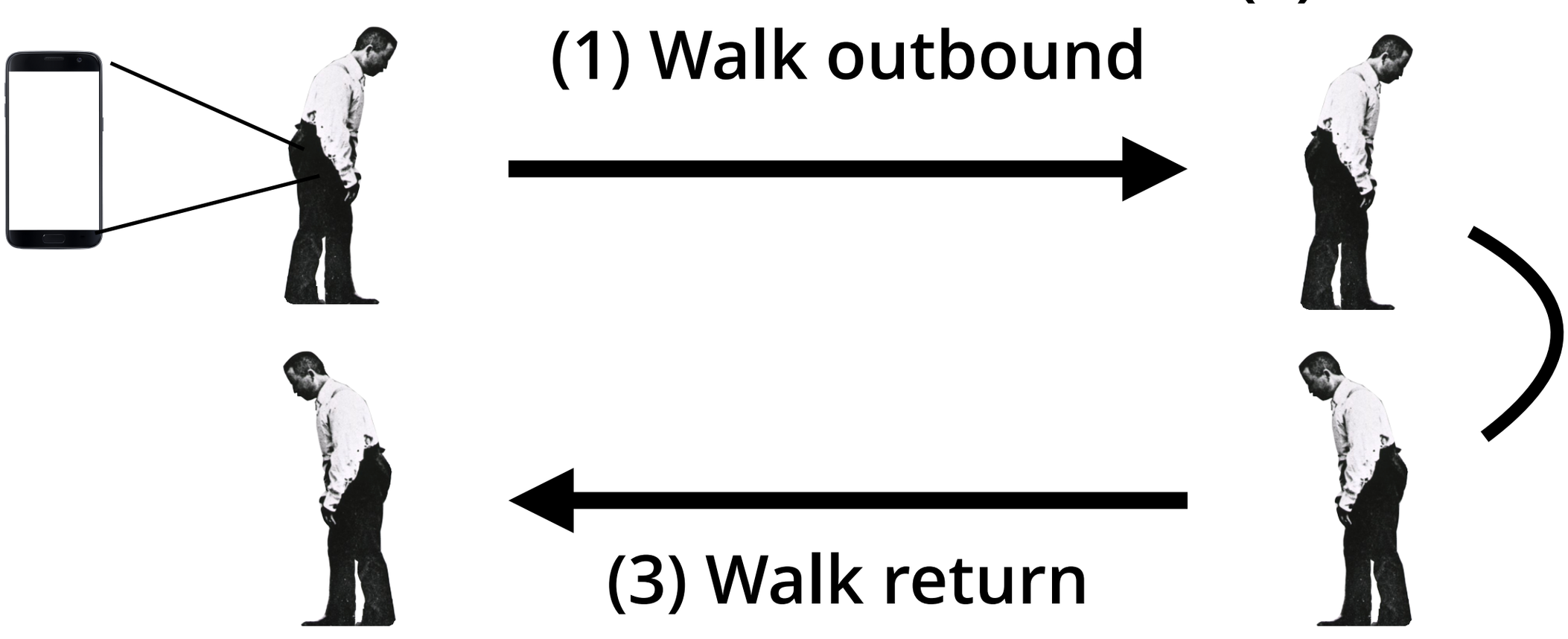
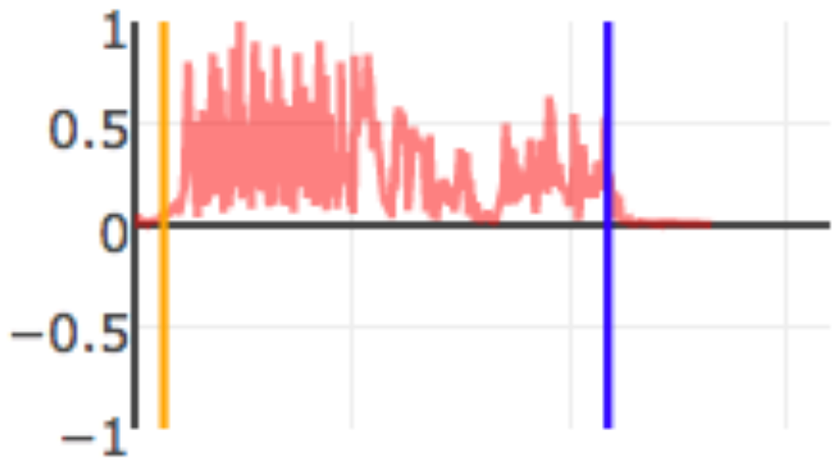


Data Streams

- Accelerometer time series:
  - Acceleration
  - Rotation Rate
  - Attitude



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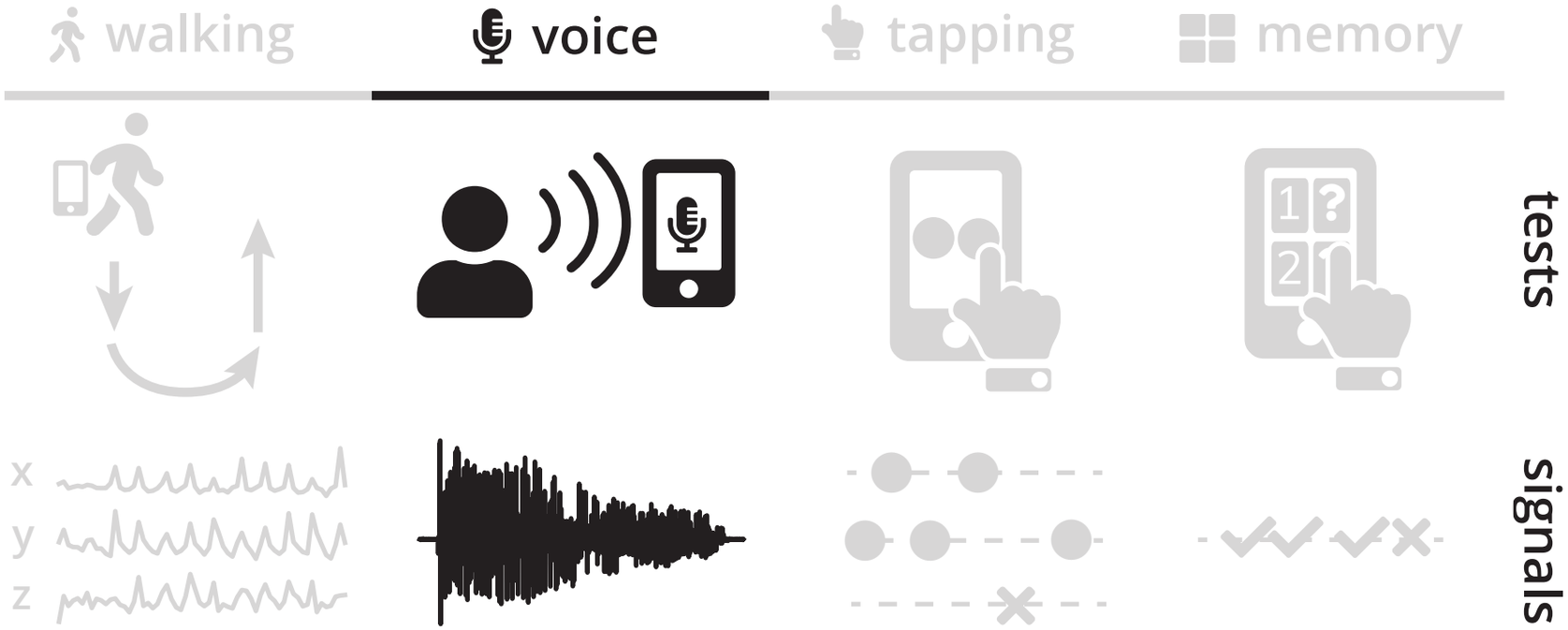


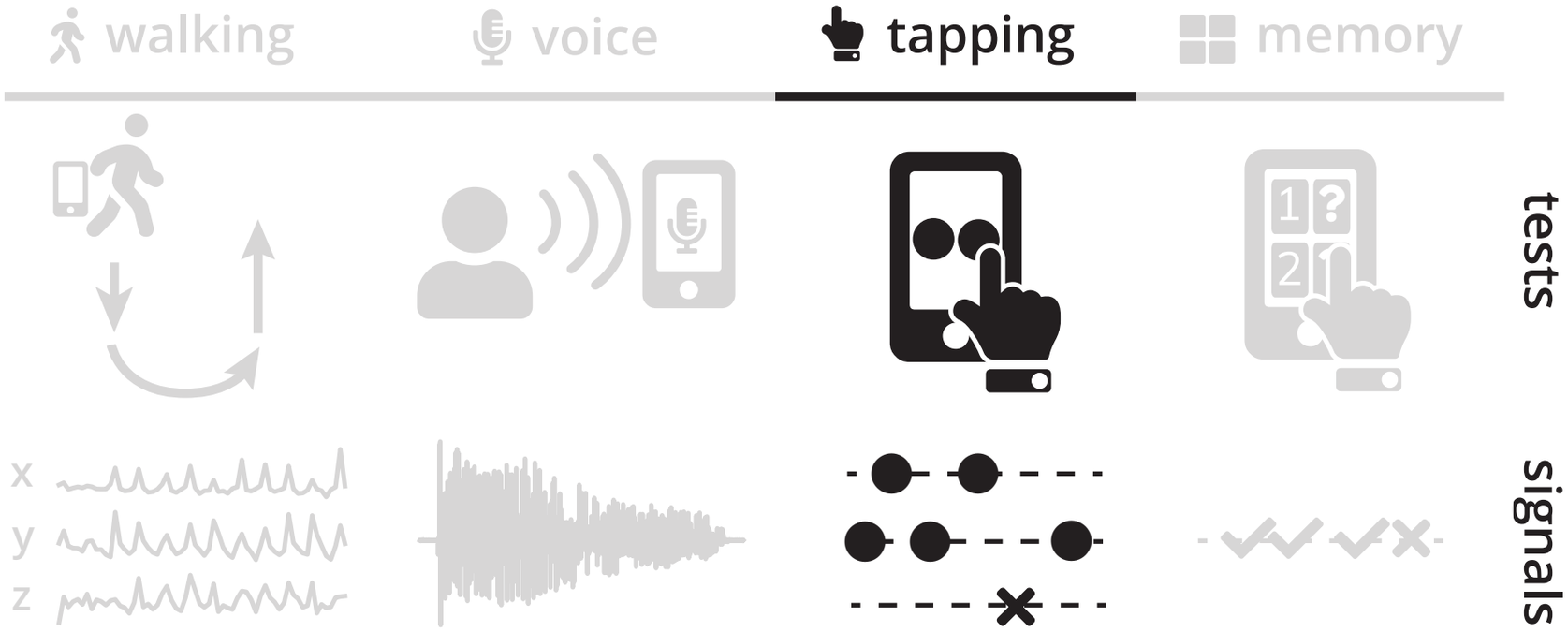
mPower Voice Test

“aaaaaah”

Data Streams

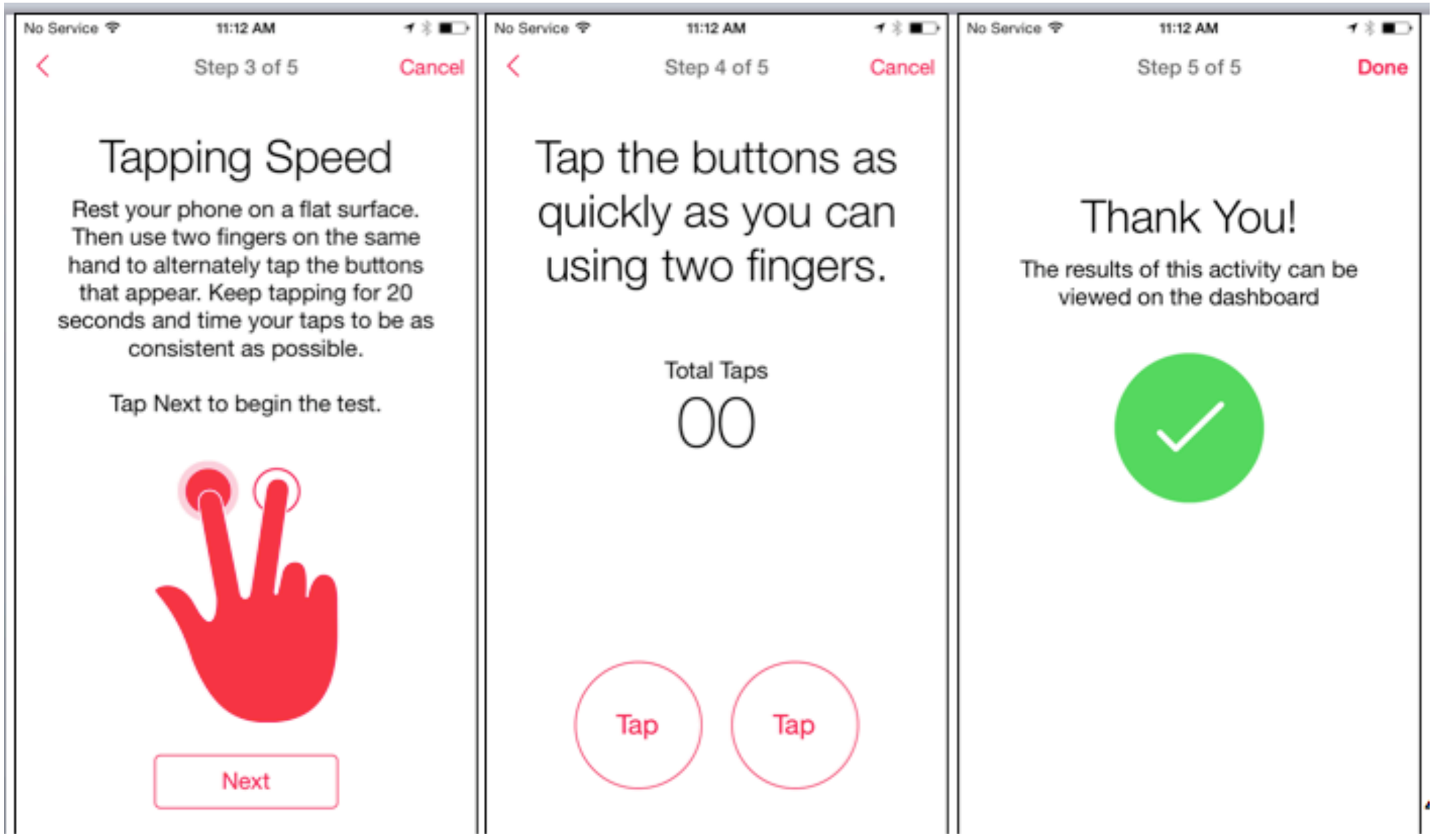
- Voice recording
  - 44100 Hz
  - ~30 seconds

Tests Overview



mPower Tapping Test

[1] Bot, B.M., et al. (2016) *The mPower study, Parkinson disease mobile data collected using ResearchKit.* Scientific data 3.



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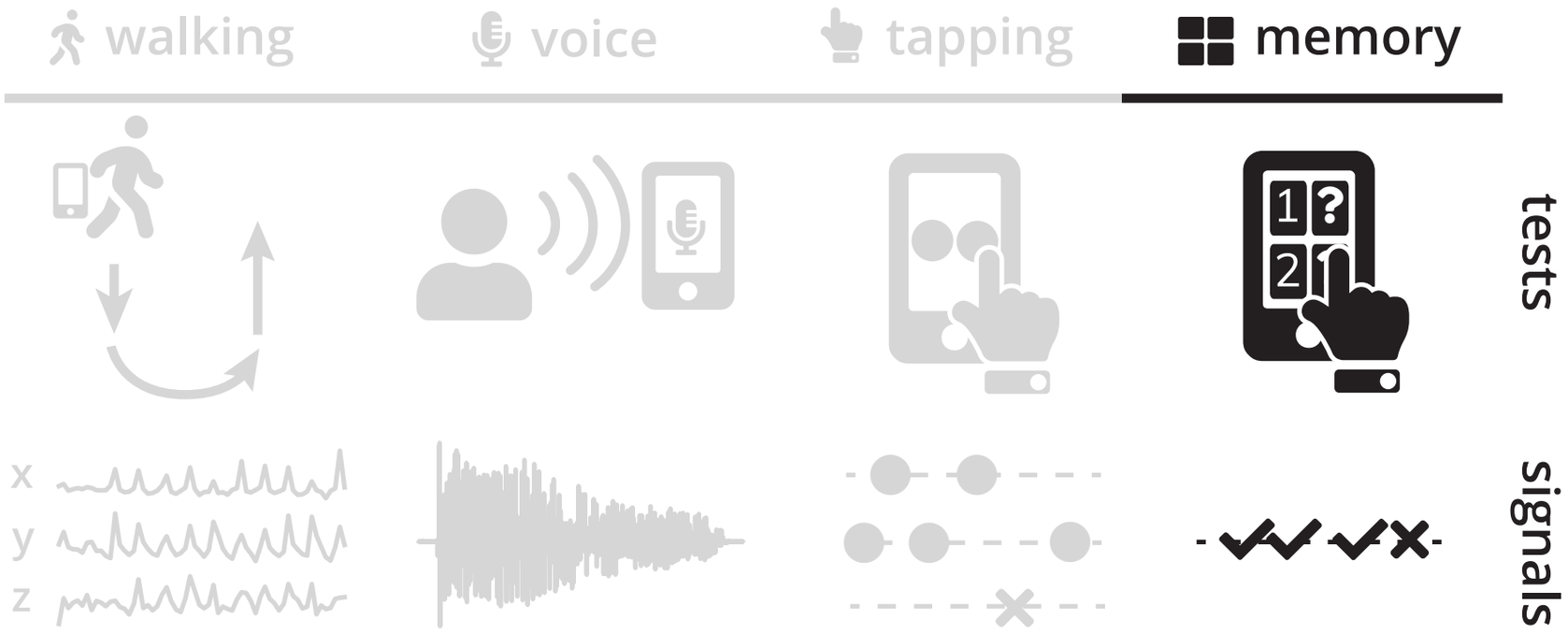

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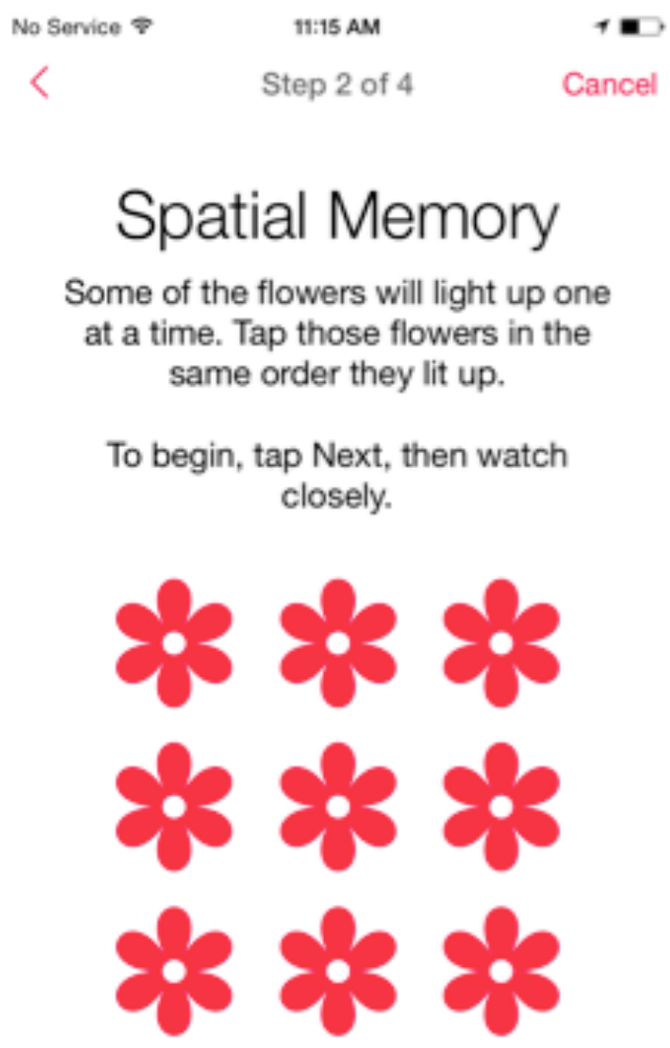
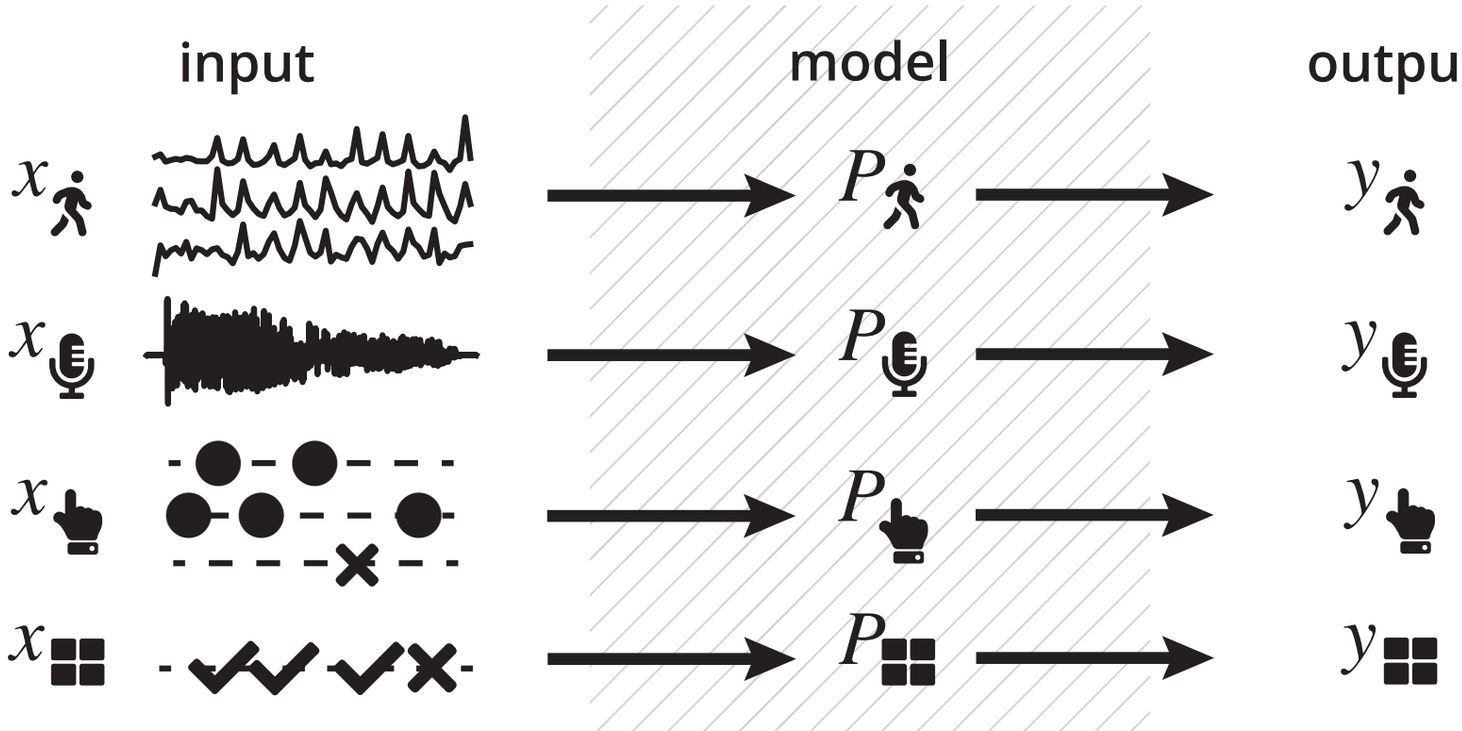


[1] Bot, B.M., et al. (2016) *The mPower study, Parkinson disease mobile data collected using ResearchKit.* Scientific data 3.

Approach

1- Hierarchical Approach

Per-test Models: Specialised in each test type.



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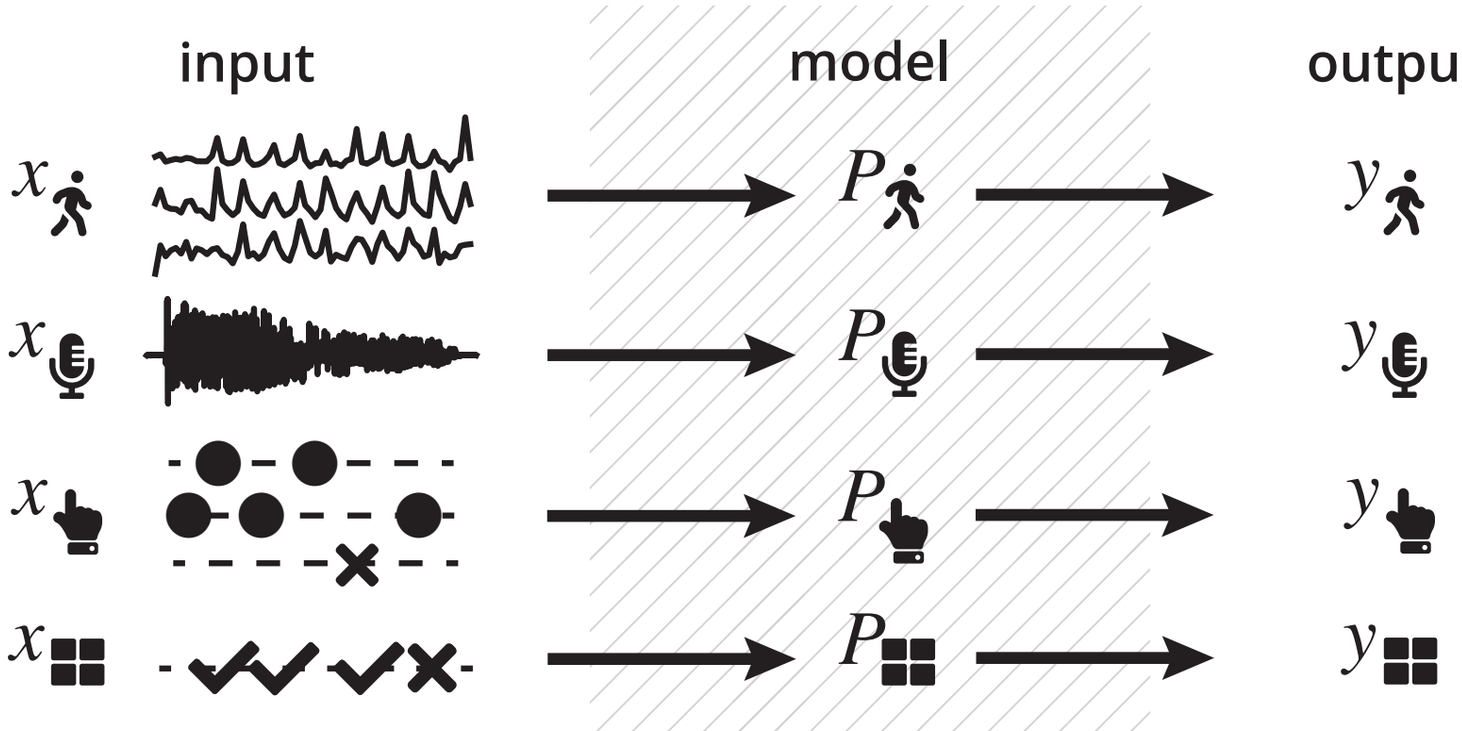
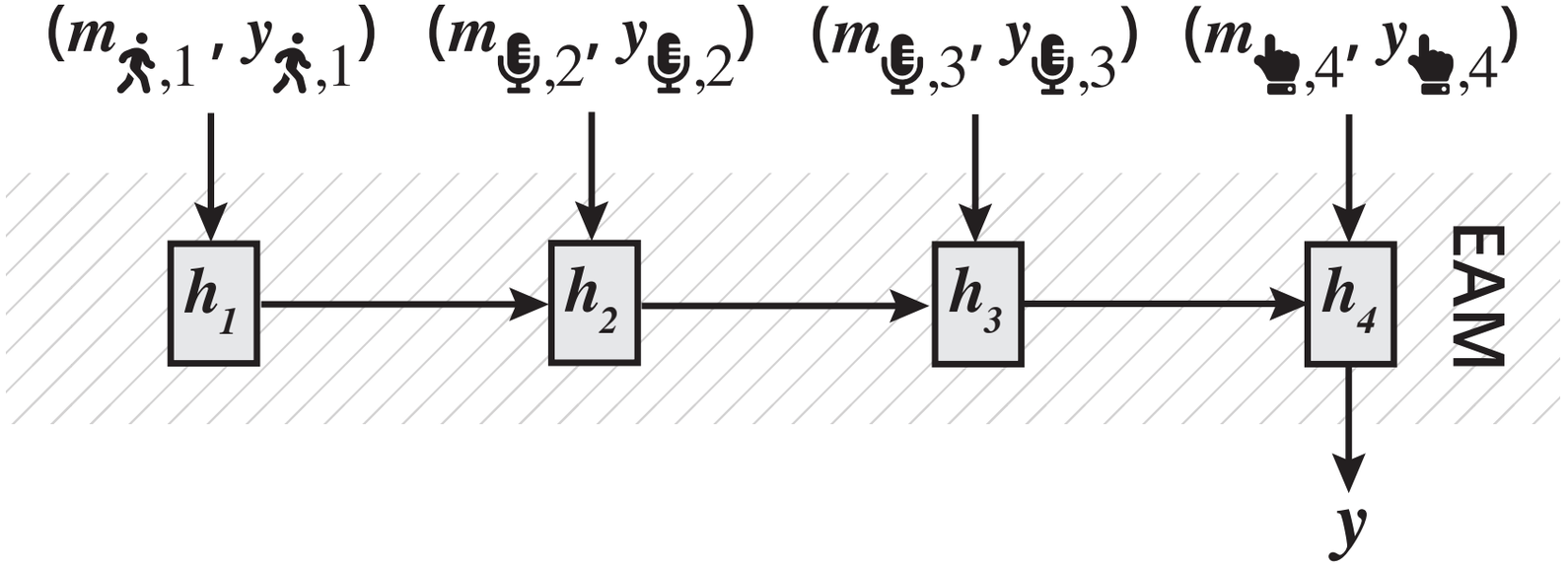


Independent models

2- Hierarchical Approach

Evidence Aggregation Model (EAM):
Integrate available test data over time.



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Evidence Aggregation Model (EAM):
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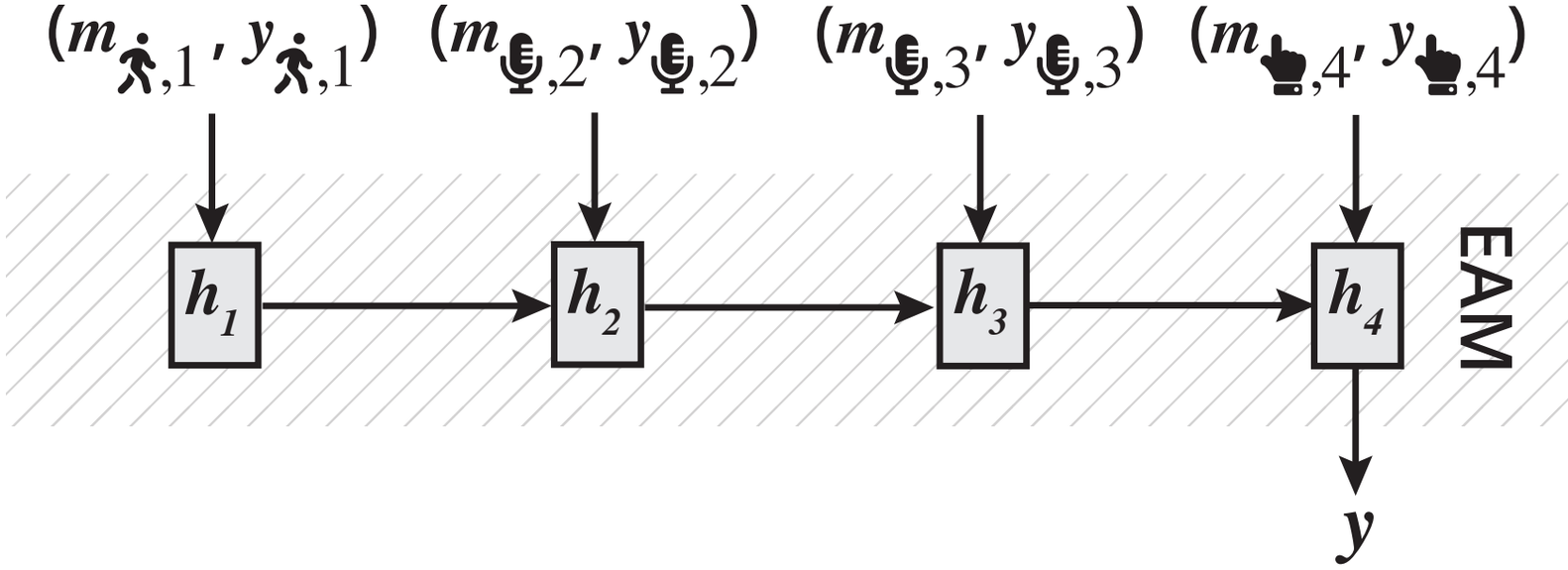
Any number of tests



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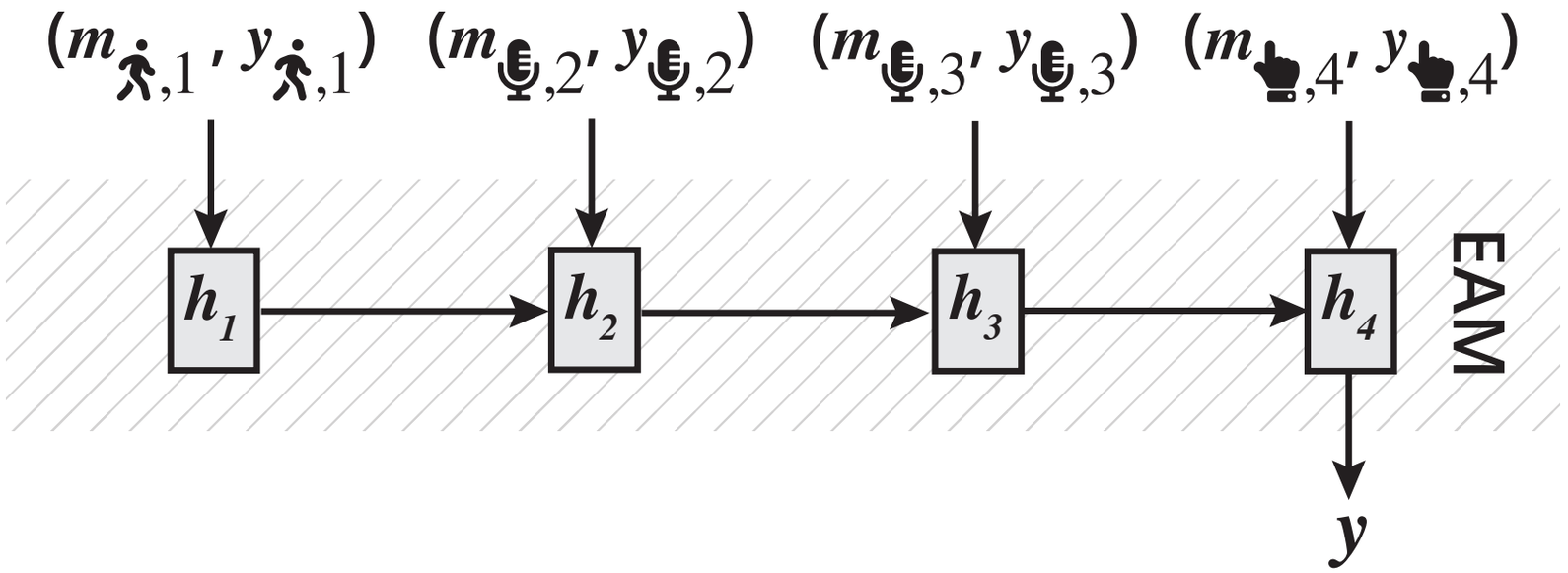
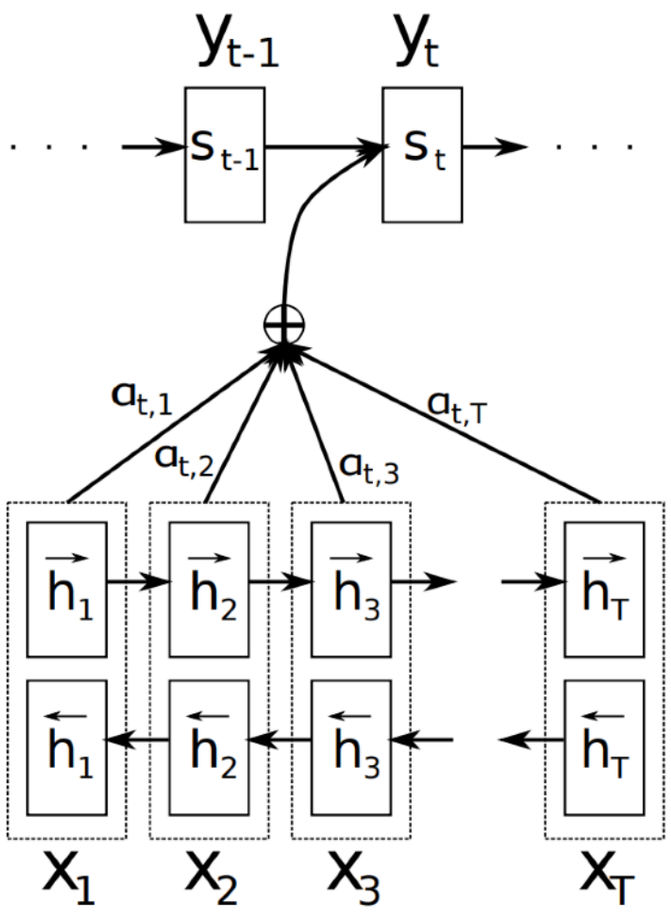
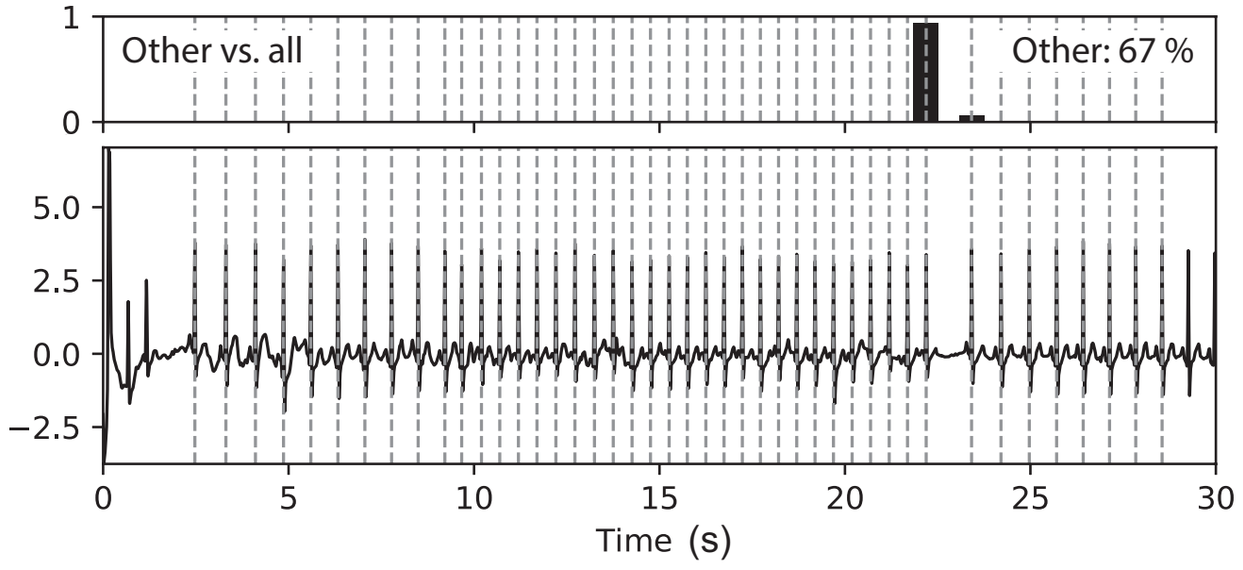


Final diagnostic score

Neural Soft Attention

- A **soft attention mechanism**[1] allows us to relate the **decisions** to the most relevant **(1) input segments**[2] and **(2) tasks.**



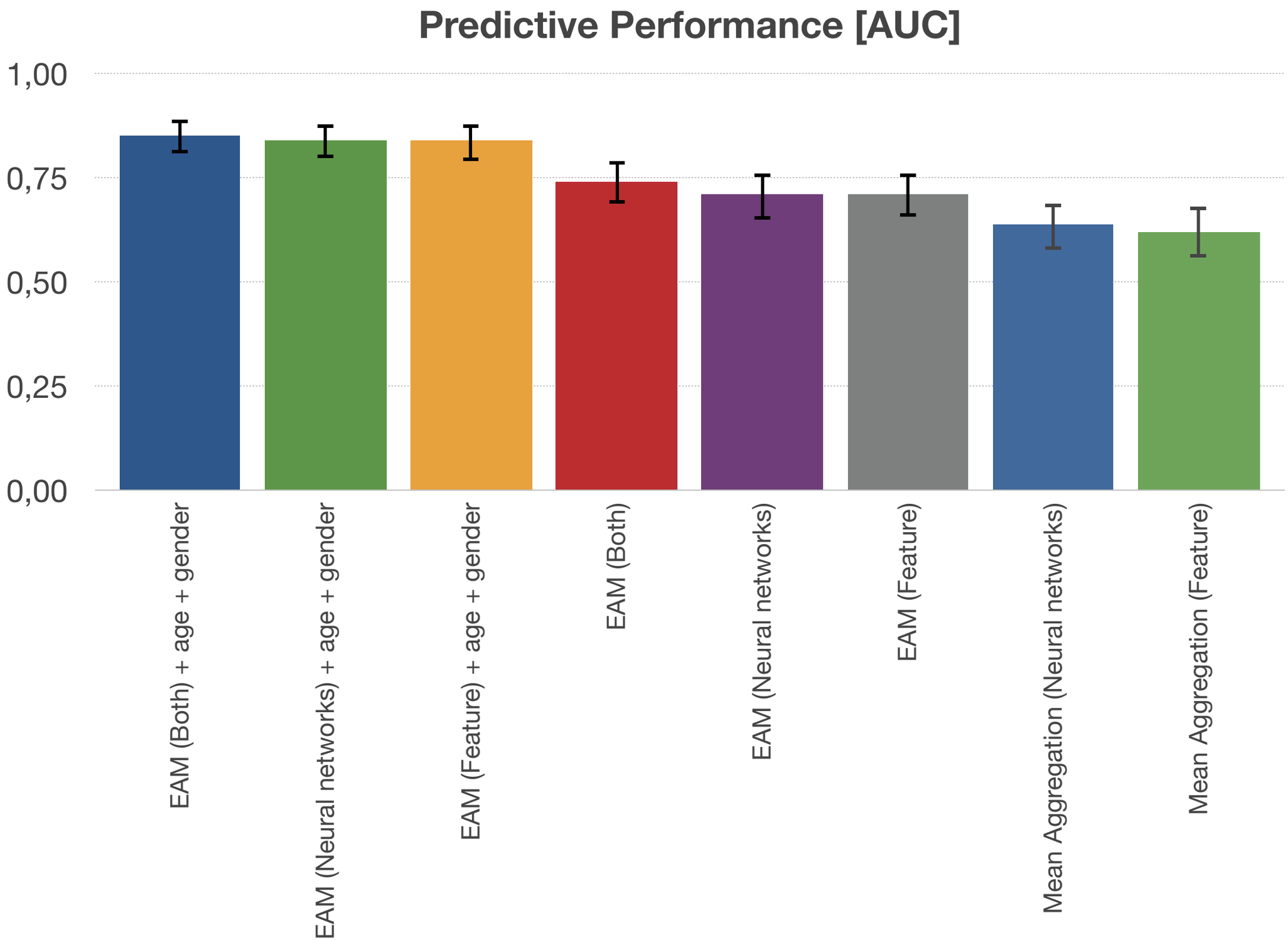


[1] Bahdanau, D. et al. (2014). *Neural Machine Translation by Jointly Learning to Align and Translate.* ICLR.

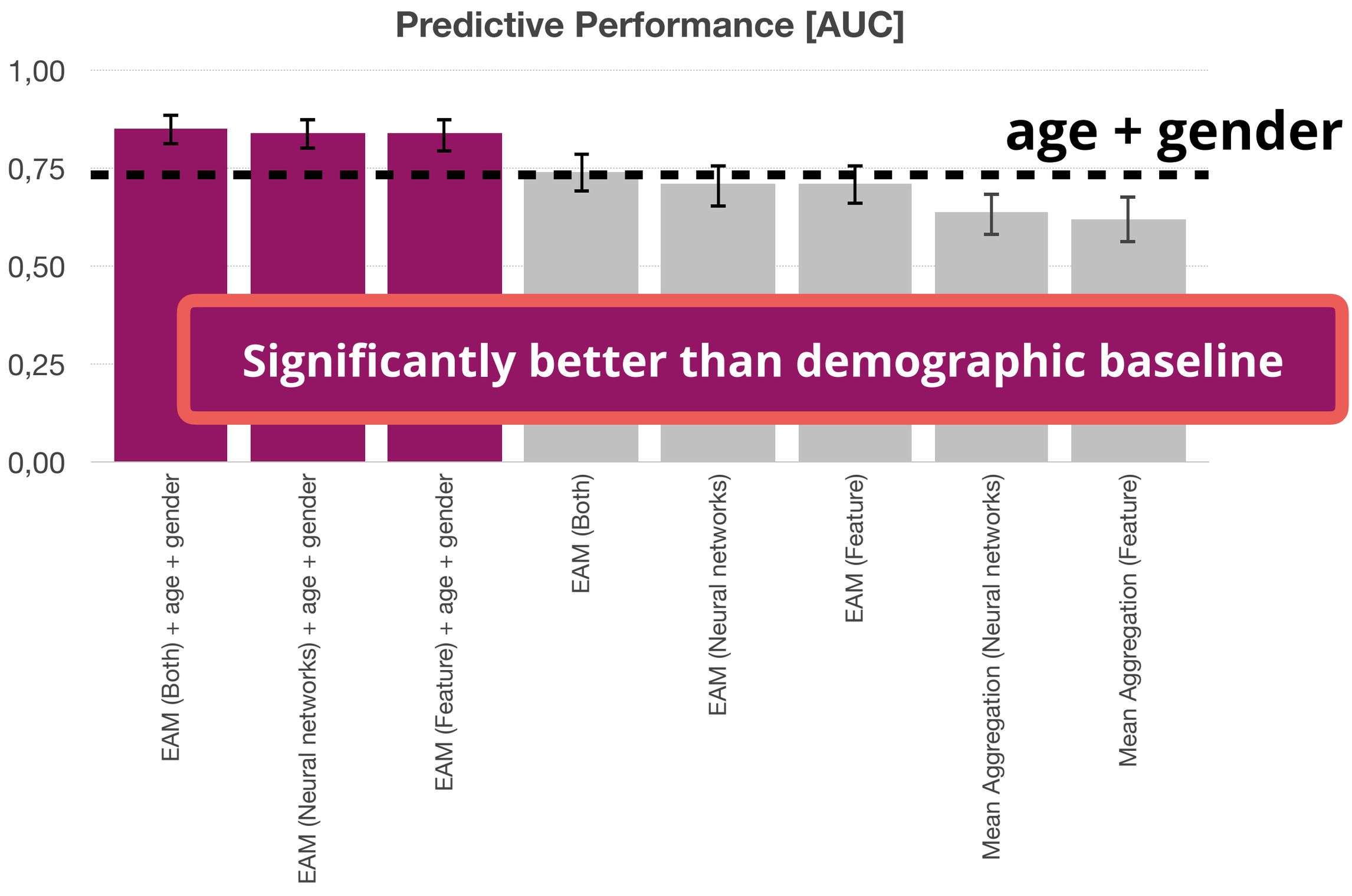
[2] Schwab, P., et al. (2017). *Beat by Beat: Classifying Cardiac Arrhythmias with Recurrent Neural Networks.* Computing in Cardiology.

Results & Discussion

Results on Test Set

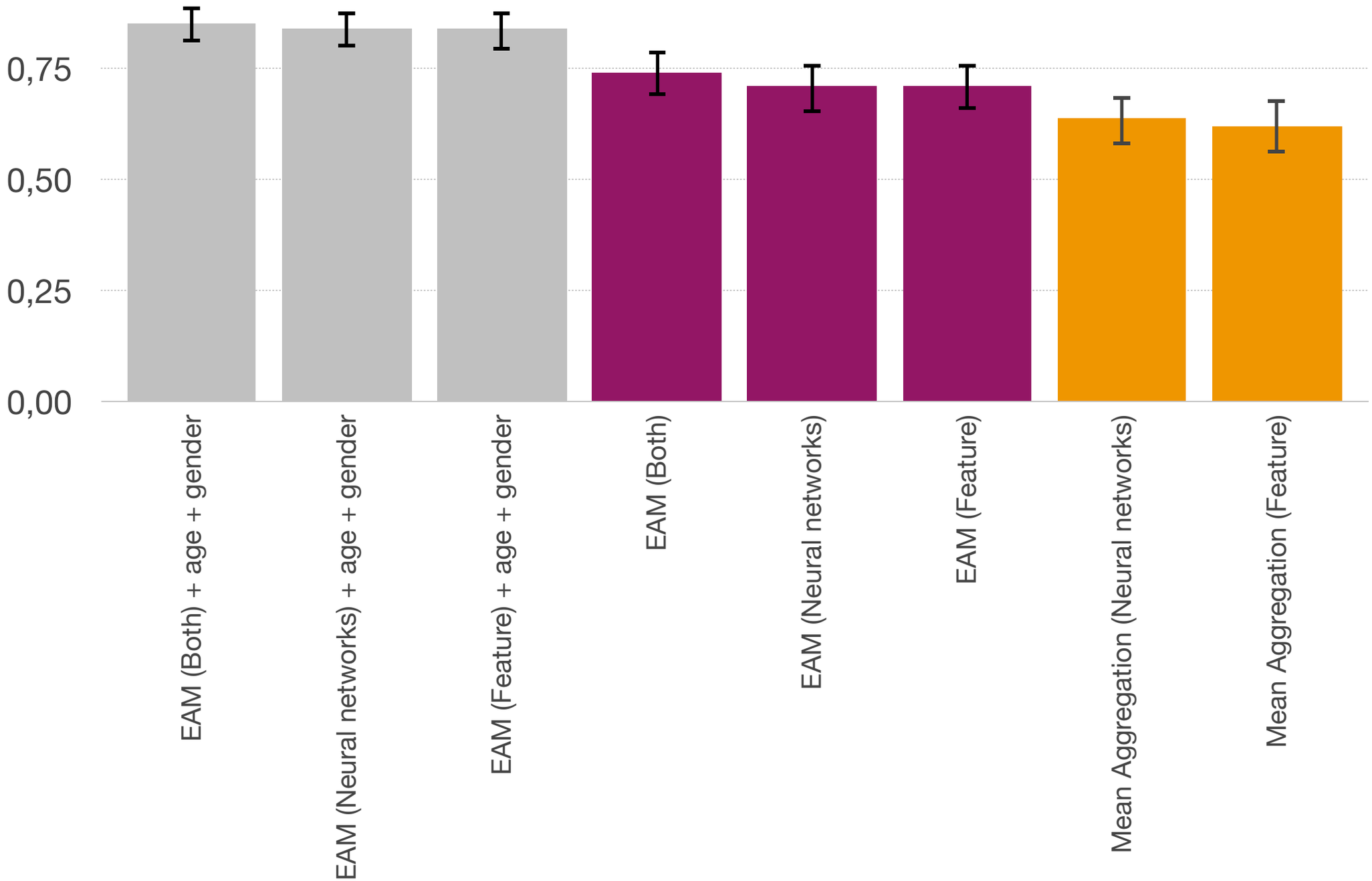


Results on Test Set

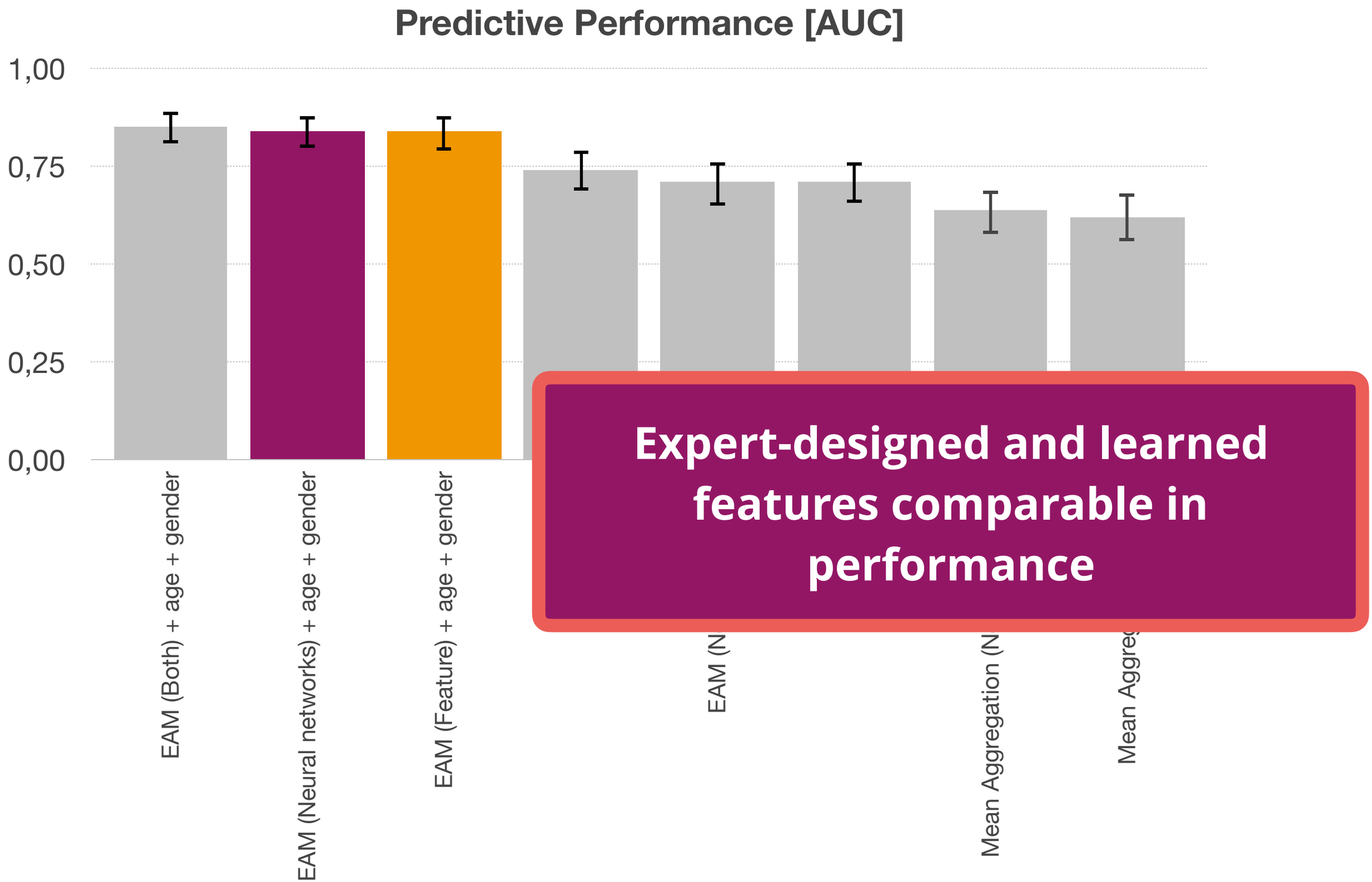


Results on Test Set

EAM better integrates the available test data



Results on Test Set



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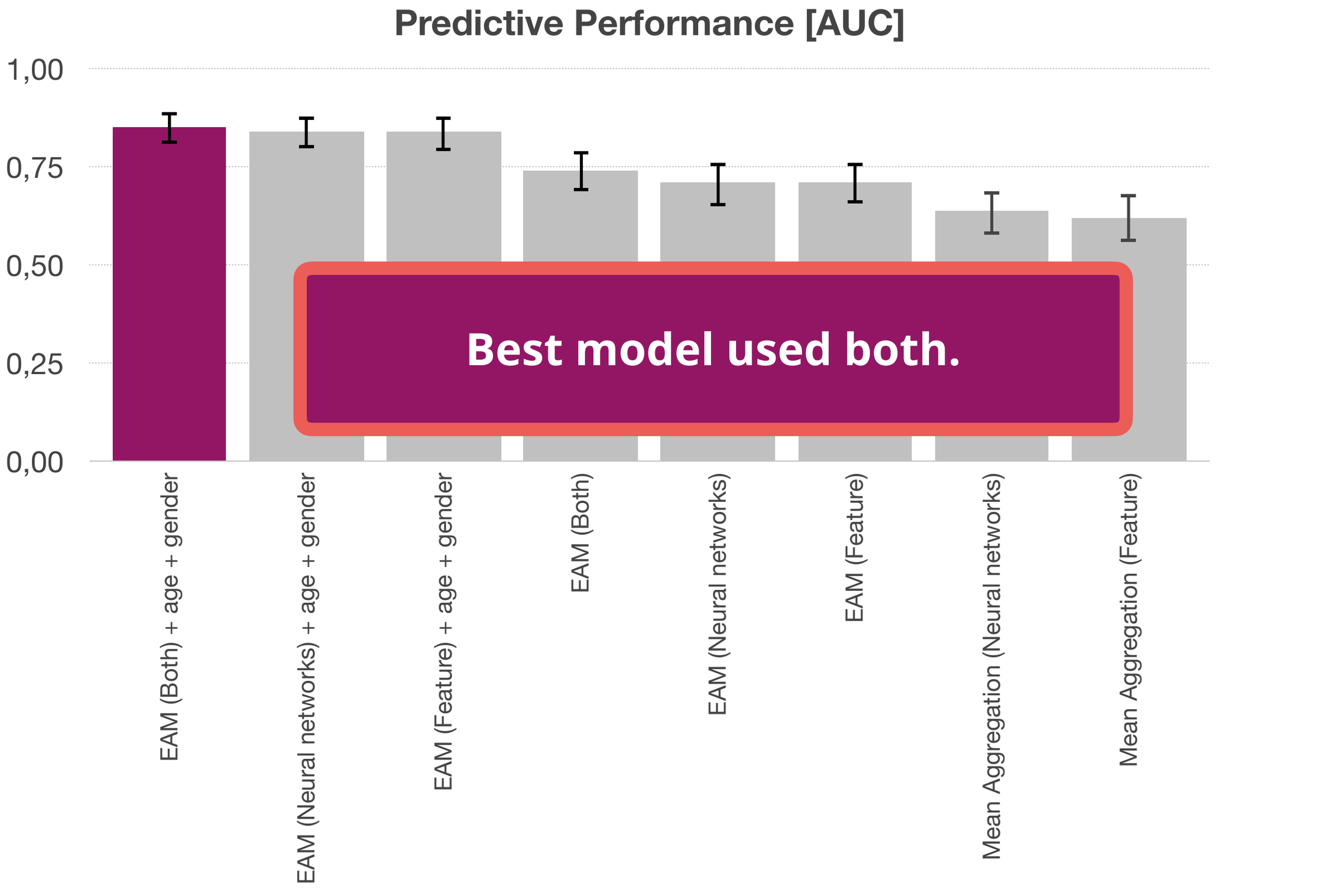
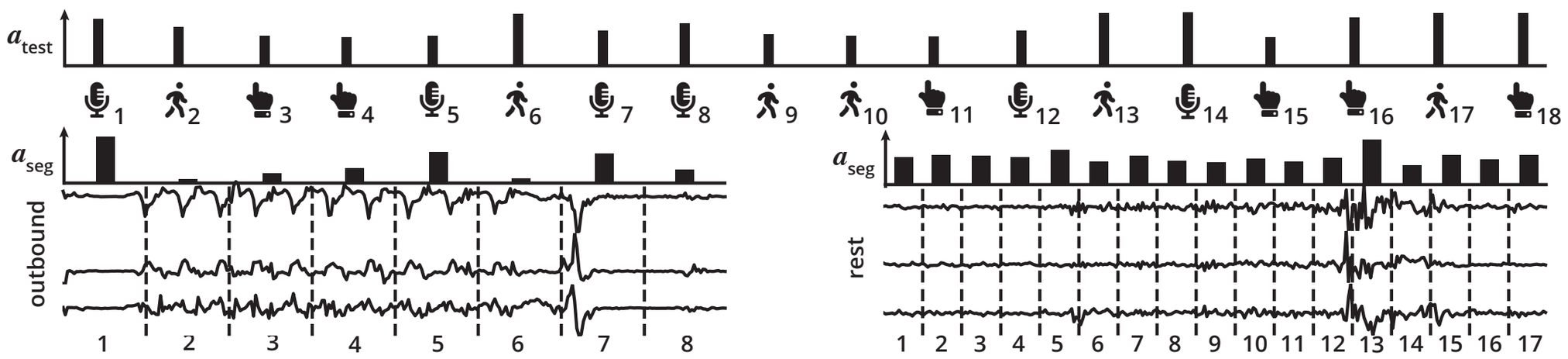
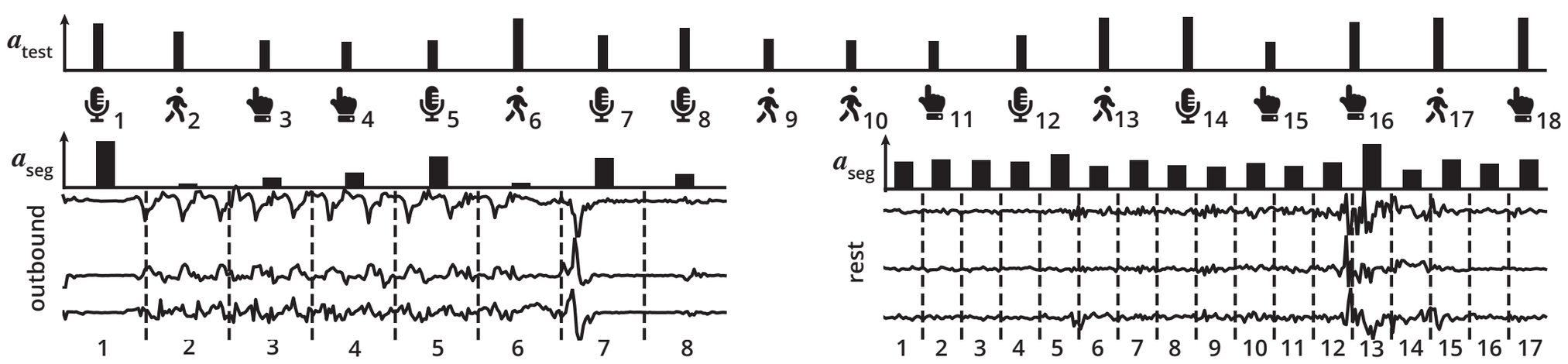


Neural Attention



Neural Attention

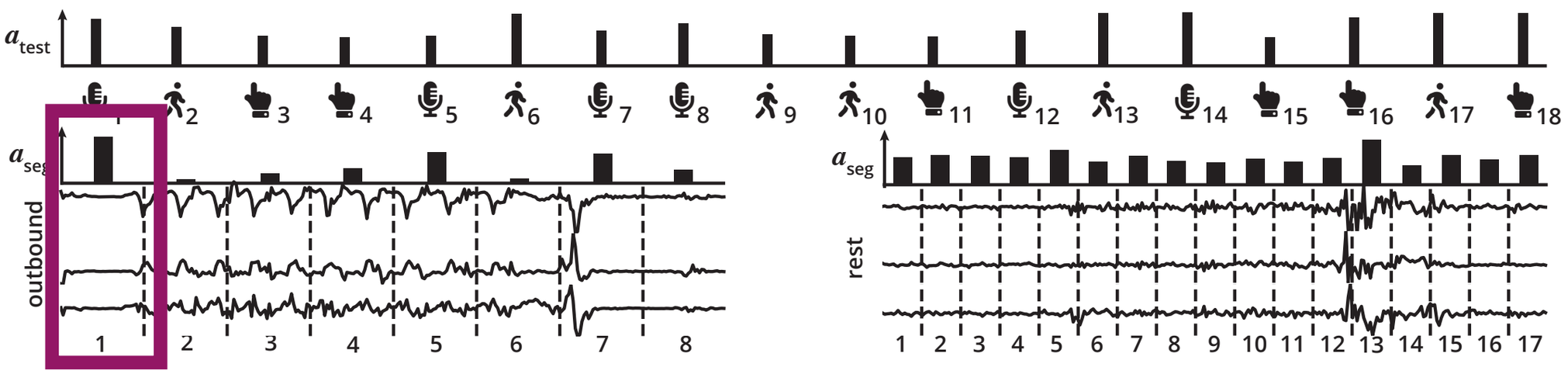
Importance over tests



Importance within test

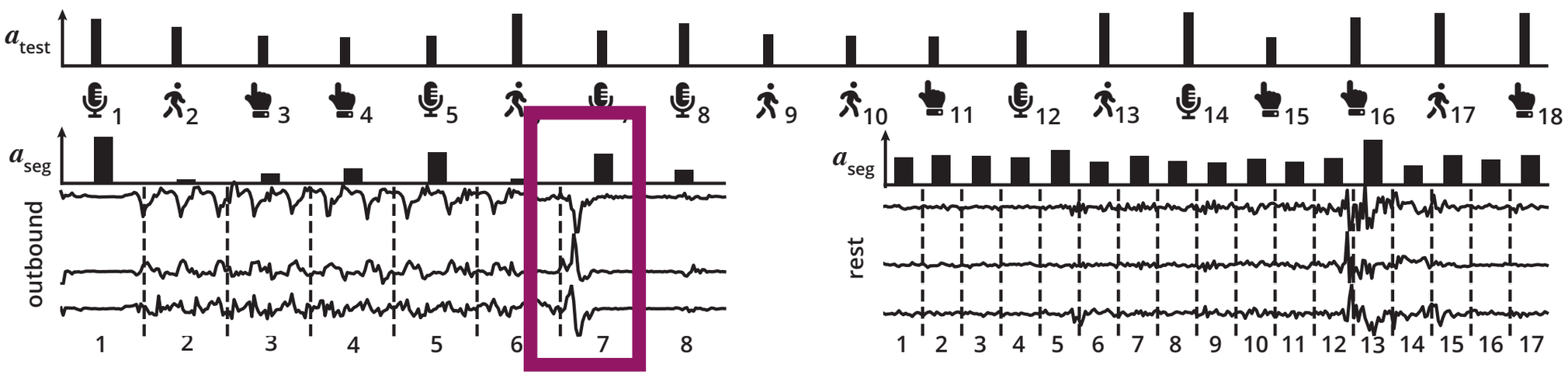
Importance within test

Neural Attention (Subject with PD)



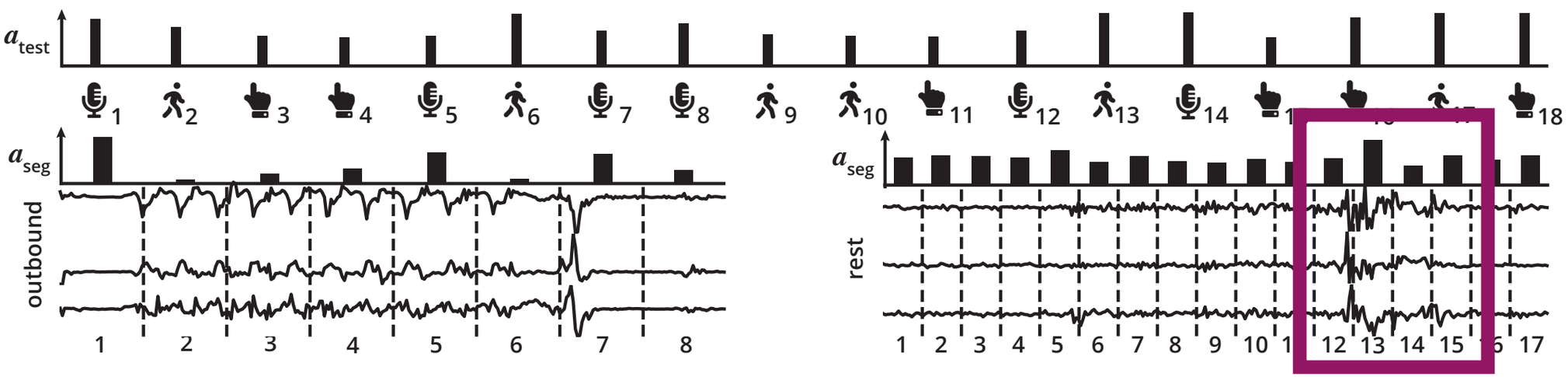
Difficulty starting to move

Neural Attention (Subject with PD)



Abrupt stop

Neural Attention (Subject with PD)



Potential resting tremor

Conclusion

Conclusion

- We present an approach to diagnosing PD that …

  ✔ **works** based on multiple smartphone-based tests that cover a **wide range of symptoms** across **long time frame**

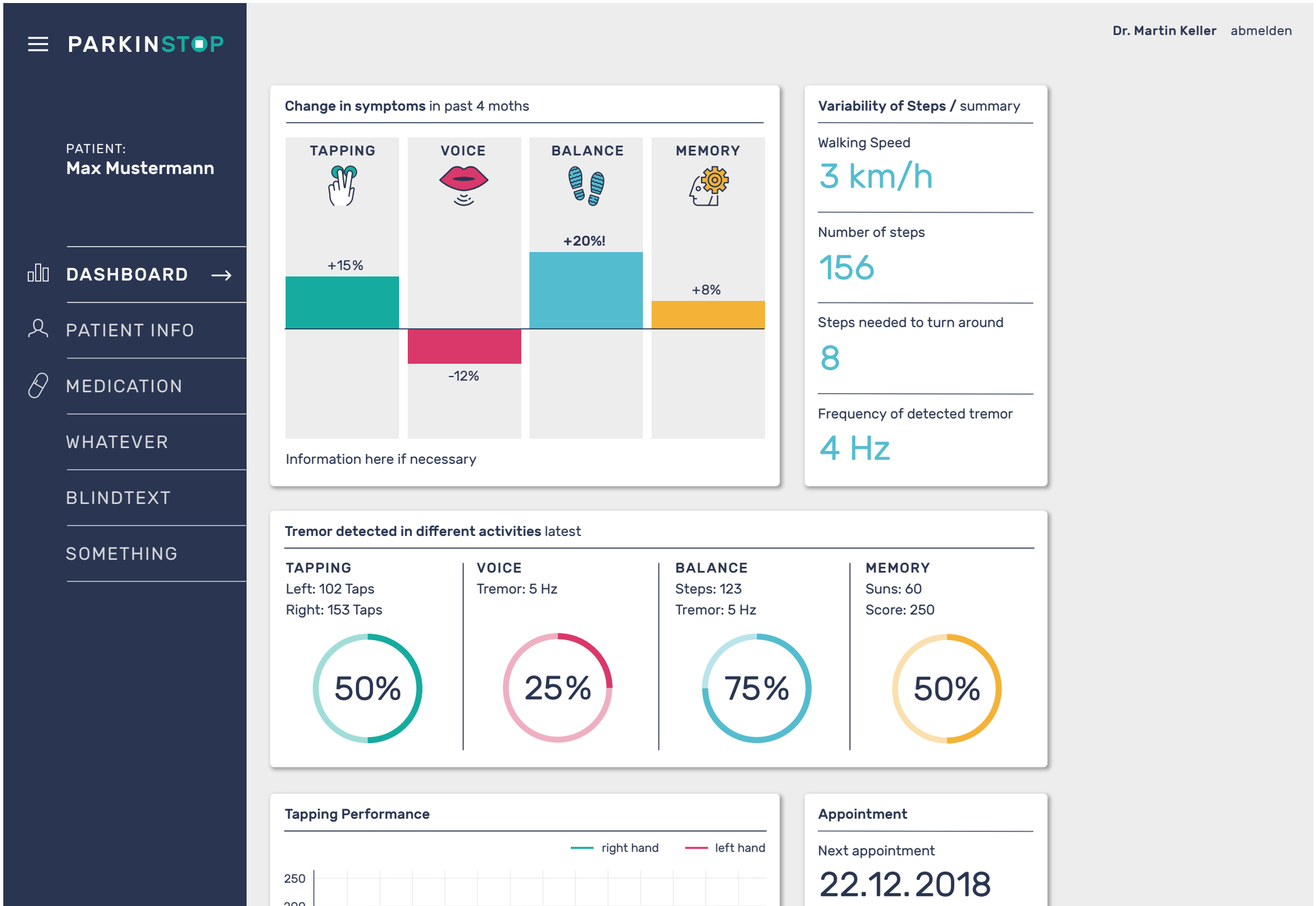
  ✔ informs the clinician about the **importance of tests and segments within those tests** using neural attention

  ✔ achieves **strong performance** in a **representative cohort (n=1853)** with an **AUC of 0.85 (95% CI: 0.81, 0.89)**

- We highlight **potential of smartphones** as accessible tools for gathering **clinically relevant data in the wild**

Future Work

[1] Matas Pocevicius (2018), Intelligent Decision-Support for Diagnosis and Monitoring of Parkinson's Disease. MSc Thesis, ETH Zurich



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Questions?

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Schwab, Patrick and Karlen, Walter.
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AAAI 2019

Dataset Overview

Property	Training	Validation	Test
Subjects (#)	1314 (70%)	192 (10%)	347 (20%)
PD (%)	52.36	50.00	56.20
Female (%)	28.00	36.98	25.94
Age (years)	59.29 ± 9.40	59.53 ± 9.03	58.90 ± 9.24
Walking (#)	13.89 ± 35.07	15.58 ± 33.90	14.03 ± 45.20
Voice (#)	16.11 ± 40.21	19.47 ± 44.55	14.88 ± 45.12
Tapping (#)	15.20 ± 38.04	18.50 ± 43.12	14.78 ± 42.67
Memory (#)	14.01 ± 33.30	20.78 ± 35.92	17.58 ± 38.11
Usage (days)	24.27 ± 41.01	29.66 ± 45.73	25.43 ± 43.24

Table 3: Population statistics of the training, validation, and test set. Numbers (#) shown are mean ± standard deviation.

Dataset Overview

Largest cohort to date

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Nearly balanced

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Wide range of usage patterns