

PHYSICAL ACTIVITY EVALUATION: IMPORTANCE OF THE RAW ACCELEROMETRY SIGNAL COLLECTION

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Goals for today's talk

- Describe objective measures of physical activity (PA)
- Show their usefulness in epidemiological and clinical studies

Commercial Activity Monitors



Commercial devices

Plenty of devices show a measure of “physical activity” via so called “**activity counts**”

Usually reported quantities are:

- Number of steps
- Calories burned

How accurate are those numbers?

Commercial devices

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Usually reported quantities are:

- Number of steps
- Calories burned

How accurate are those numbers?

Some problems:

- We don't know what activity is performed
- Measures are usually based on thresholds

From: Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data

JAMA. 2015;313(6):625-626. doi:10.1001/jama.2014.17841

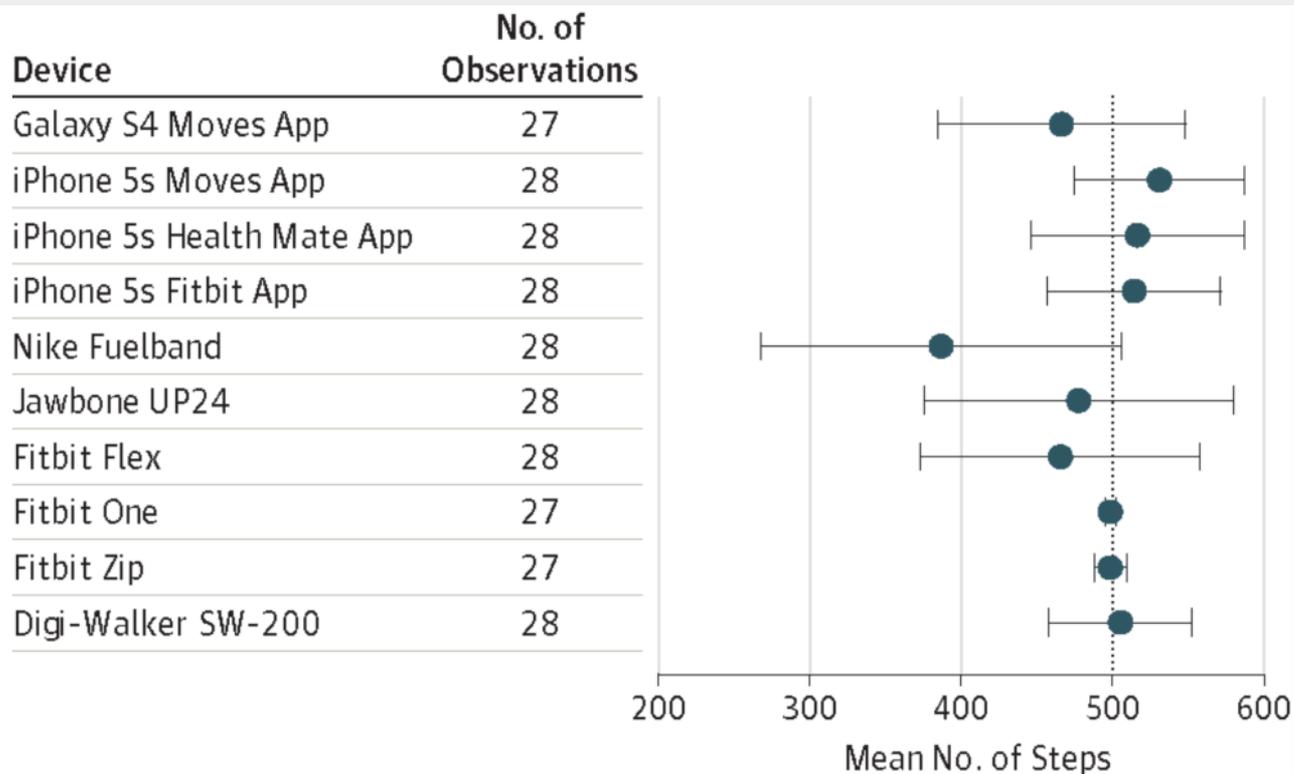


Figure Legend:

Device Outcomes for the 500 Step Trials The vertical dotted line depicts the observed step count. The error bars indicate ± 1 SD.

Real life stories

- Activity count (“steps”) while driving
- Activity of “stay-at-home mothers” and “working mothers”
- MS (multiple sclerosis) patients

Activity monitors

- Relatively popular approach is to use acceleration measurements
- **Actigraphy** is a non-invasive monitoring of human rest/activity cycles. A small actigraph unit, also called an actimetry sensor, is worn by a subject to measure motor activity.

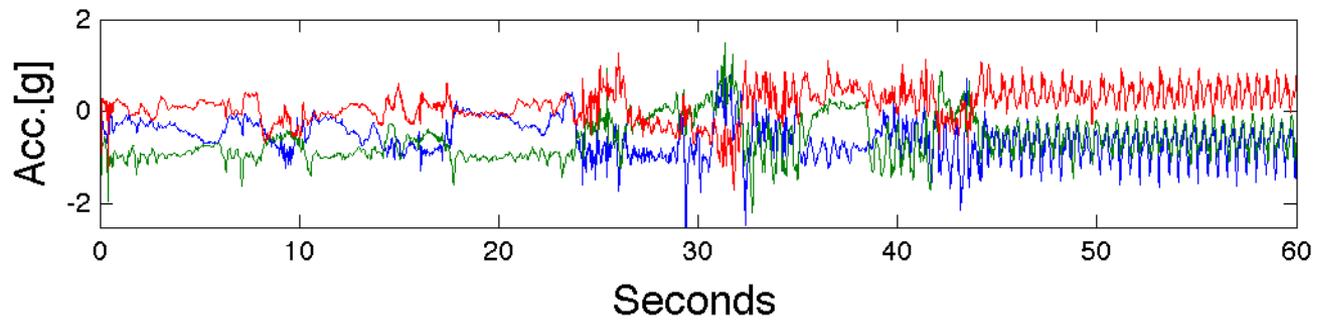
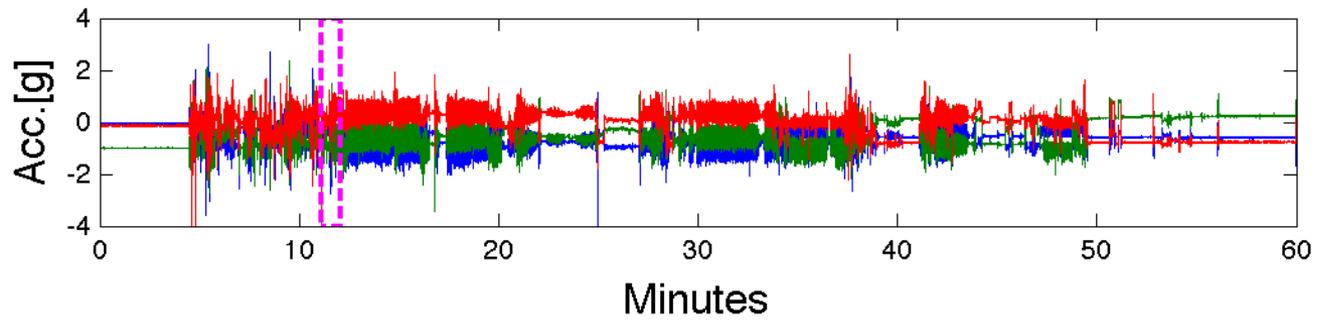
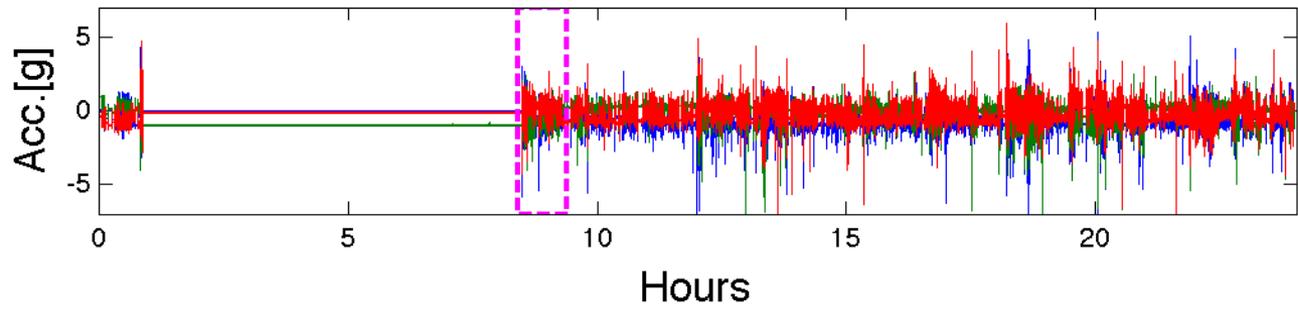


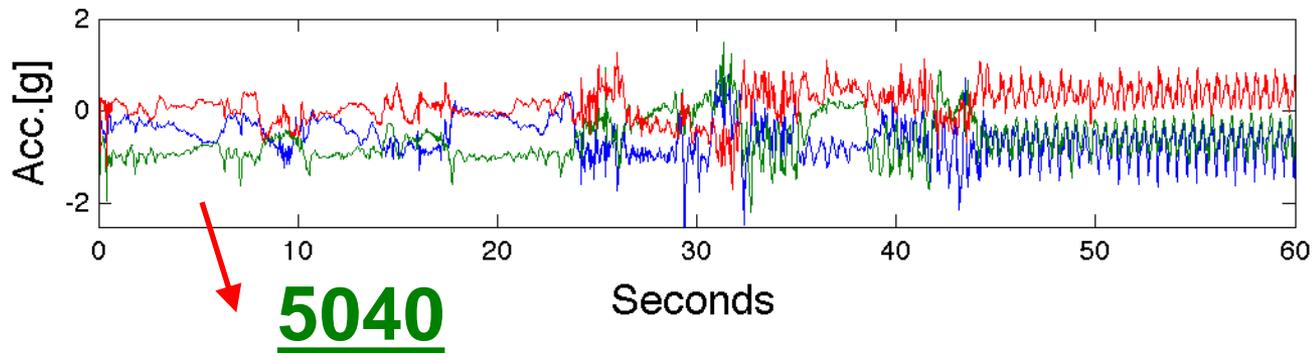
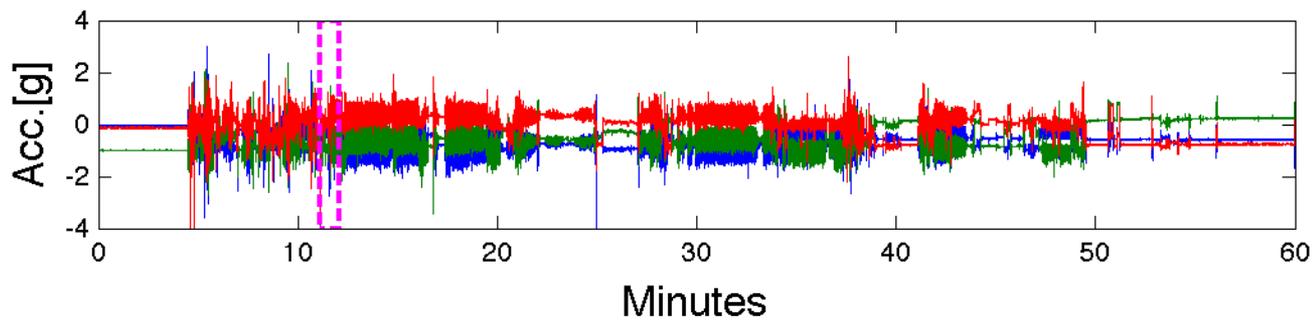
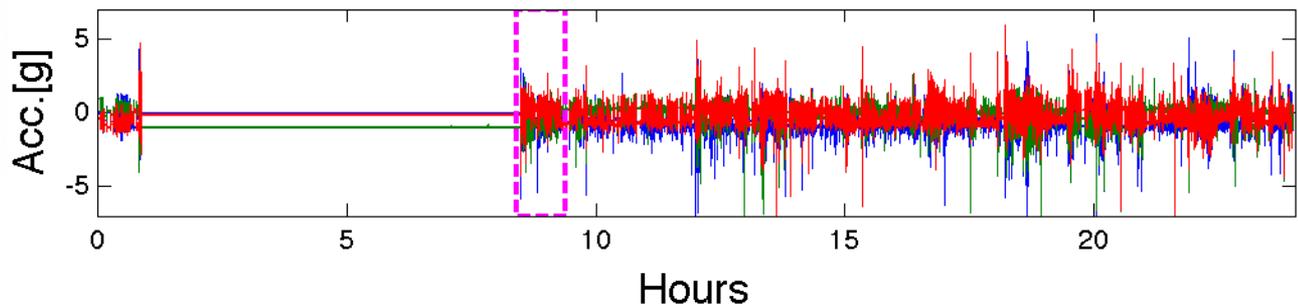
Research goals

- **Personal level** - Quantification of the energy expenditure
- **Population level** - Association of the energy expenditure with health-related measures, e.g. “quality of life”, “mobility”, “fatigability”

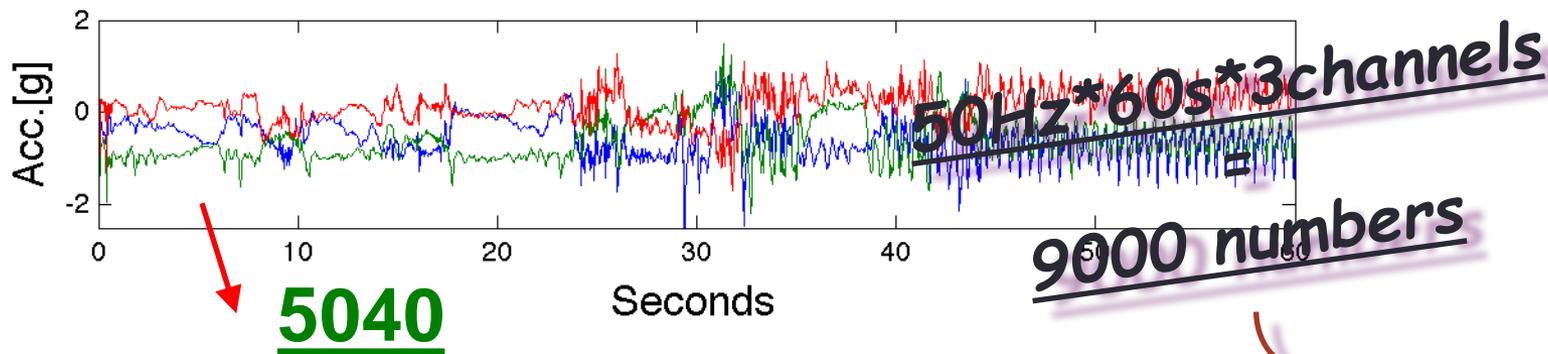
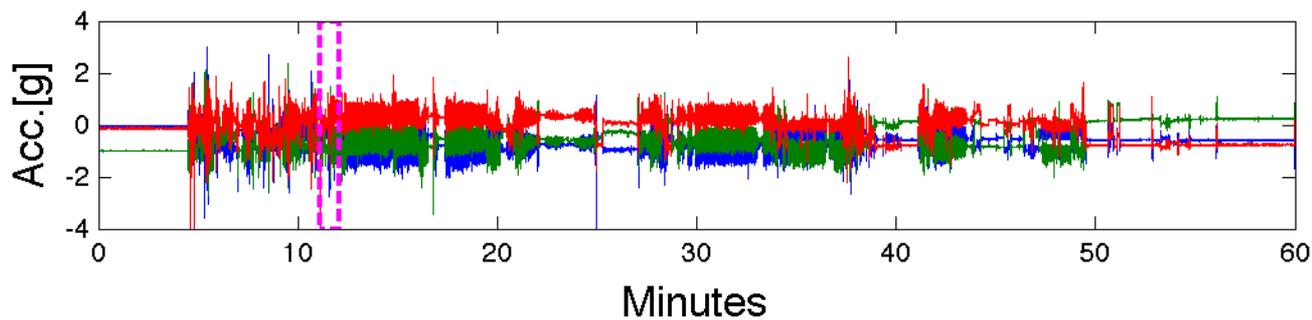
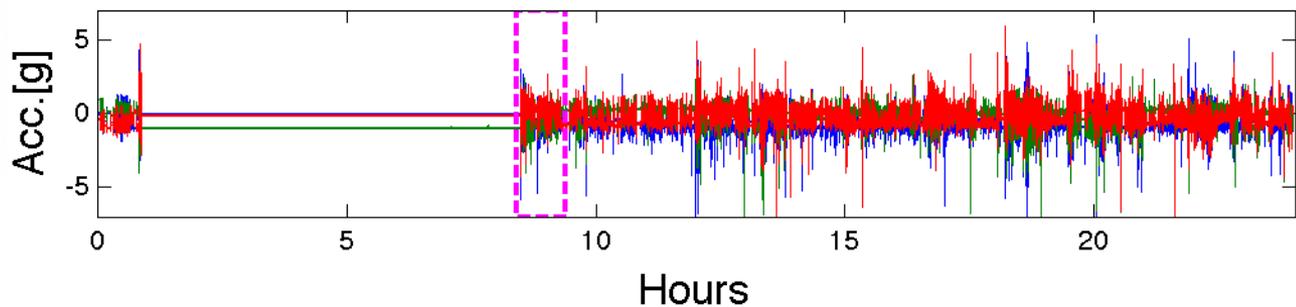
How we see the data:

Acquired acceleration values form a non-stationary time series that reflect history of subjects' real-life activities





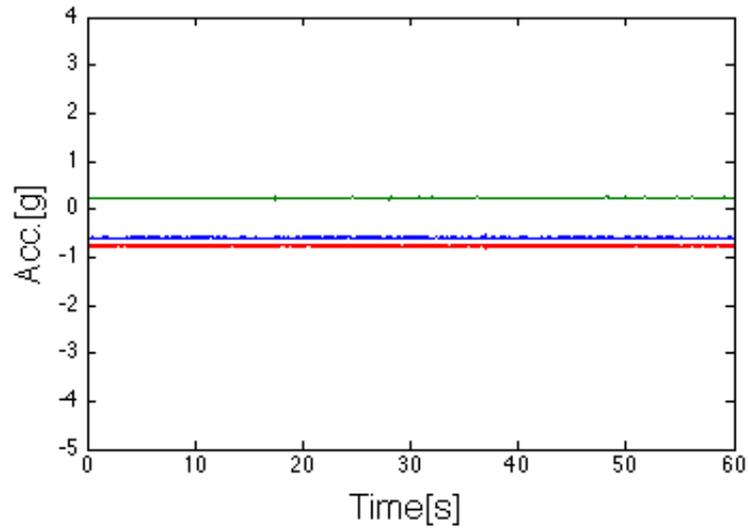
Activity Count



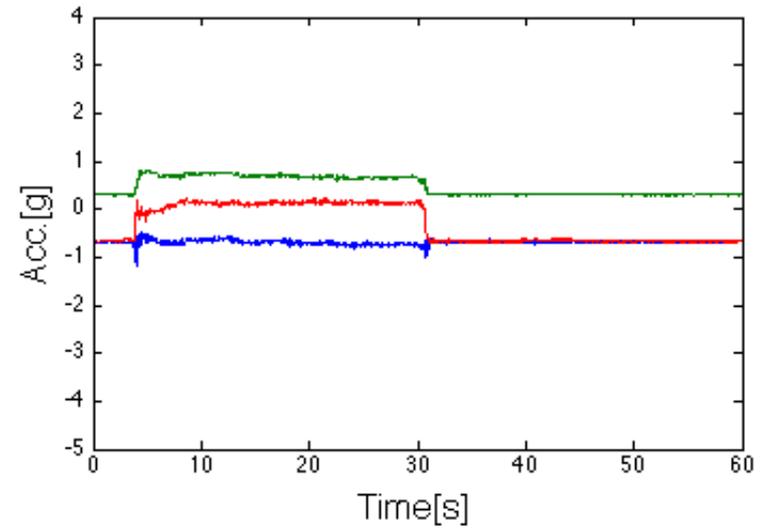
5040
Activity Count

50Hz*60s*3channels
9000 numbers
1 count

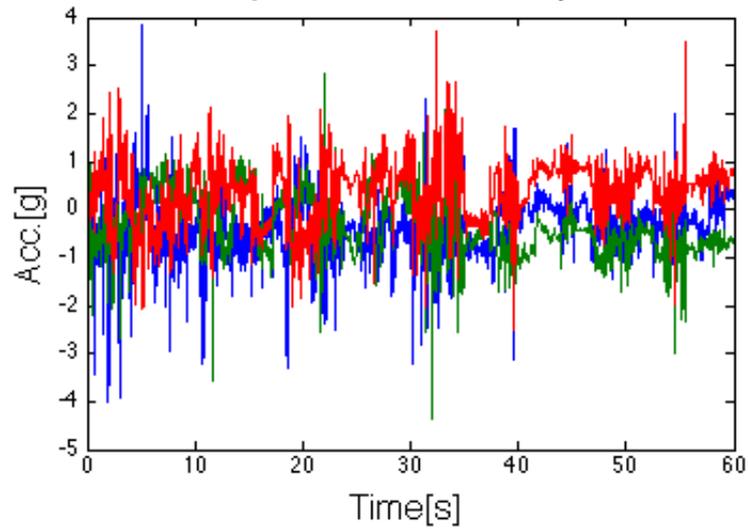
Resting



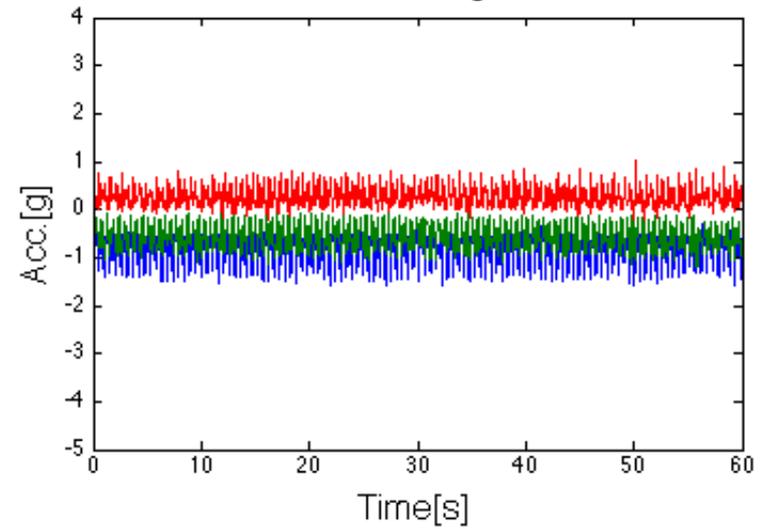
Hand position change



Non-periodic activity



Walking



Can we identify types of activity?

How can we extract more information from the raw signal?

- First, we will look at “in-the-lab” experiment
- Second, we will apply the activity detection methodology to “in-the-wild” (free-living) activity

DECOS study @ University of Pittsburgh

- Study of older adults: 70+ year old
- N = 49 participants enrolled
- Data collected in the lab on about 20 activities including “resting”, “upper body activities” and “lower body activities, e.g. walking”
- Free-living data obtained on everybody for 7 days

- Accelerometers used: ActiGraph GT3X+
- Raw data collected at 3 body locations:
 - Hip
 - right wrist
 - left wrist

DECOS study @ University of Pittsburgh

DATA

Can be extracted in either proprietary binary format or in a “flat CSV file”

“In-the-lab” data: **200 MB** per participant

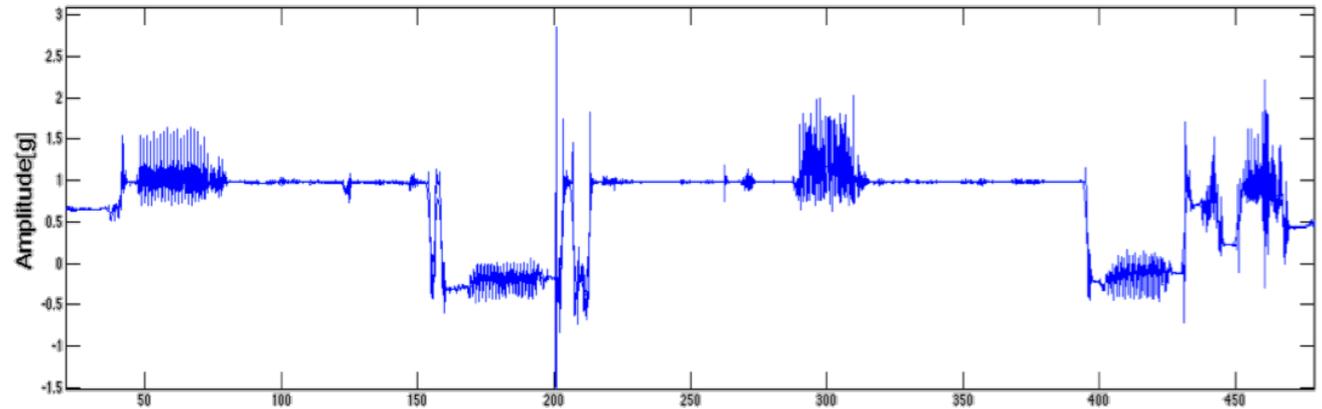
“In-the-wild” data: **5-6 GB** per participant

Approx. **500 GB of data** for a small study

Identification of movement

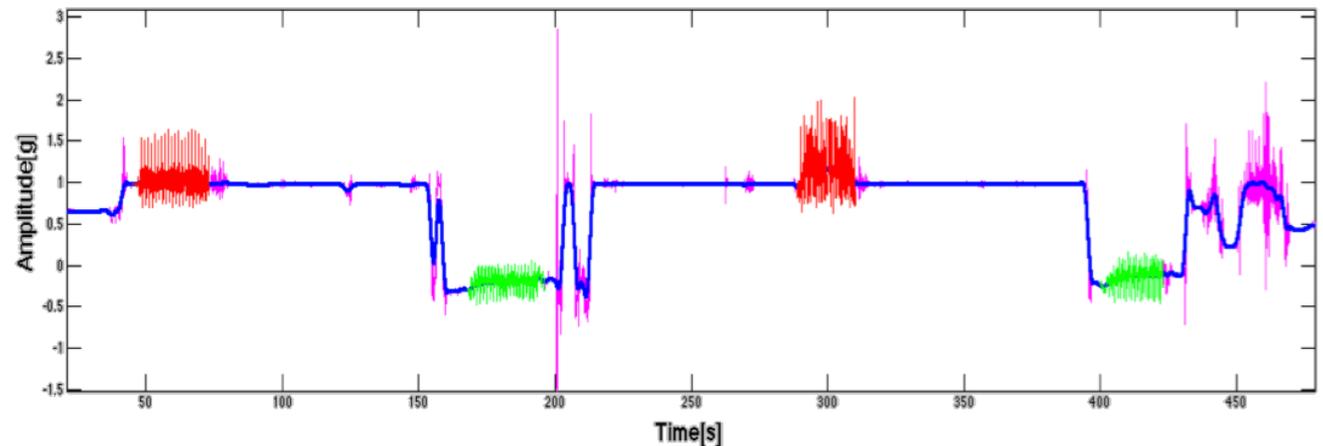
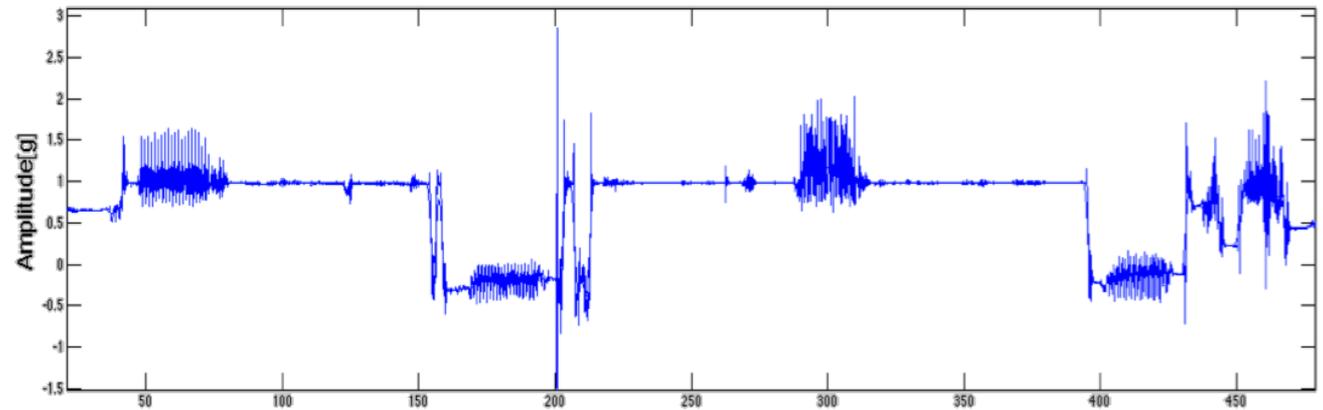
Is it possible to automatically identify walking patterns?

How can we decompose activity signals?



???

Decomposition of activity signals



- Walk (swing)
- Walk (no swing)
- Sensor position
- Other activity

How to identify walking automatically?

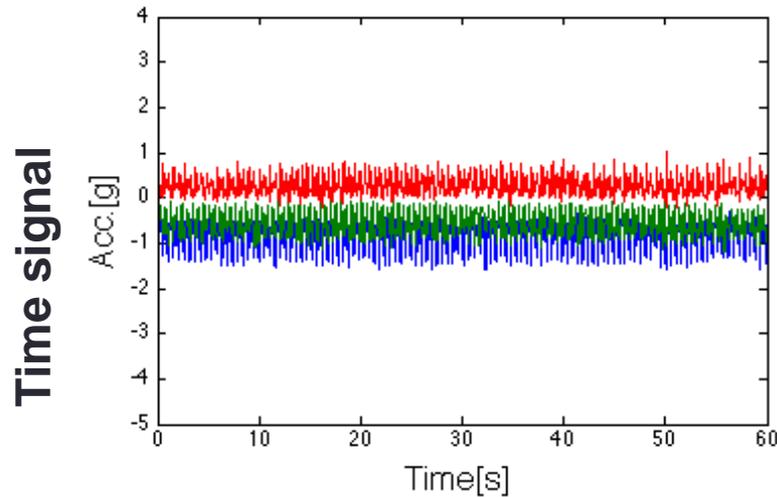
Principles

We want our method to be universal:

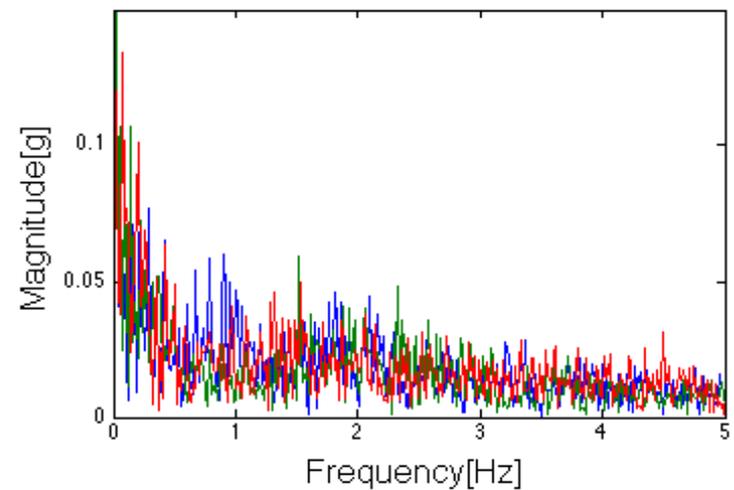
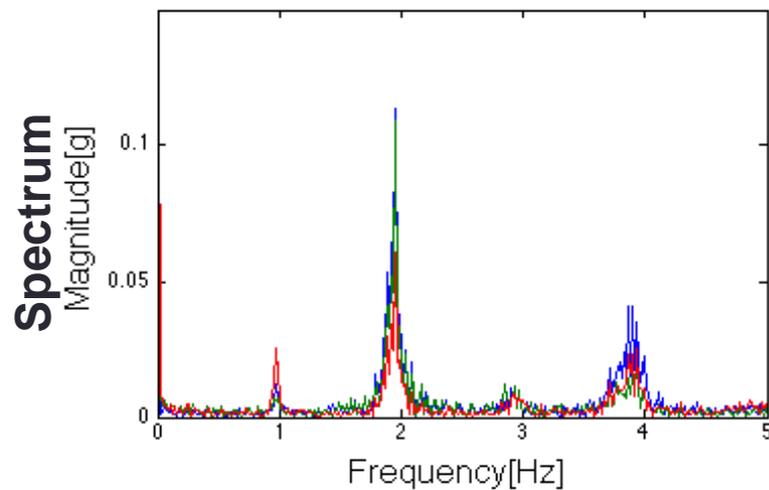
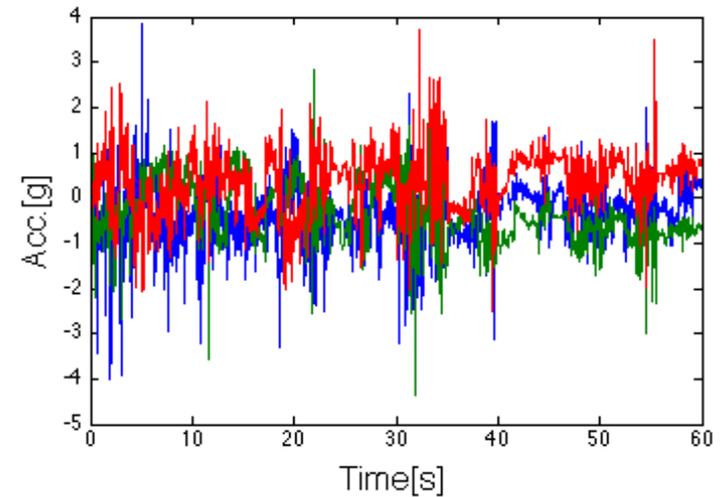
- Automatic
- Subject independent
- Device independent
- Sensor placement independent (hip, wrist, chest, ankle)

Frequency analysis

Walking (quasi-periodic)

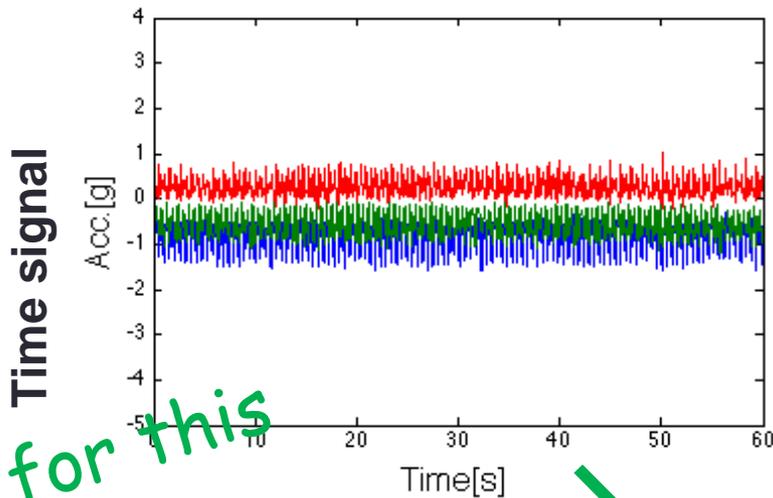


Another activity (non-periodic)

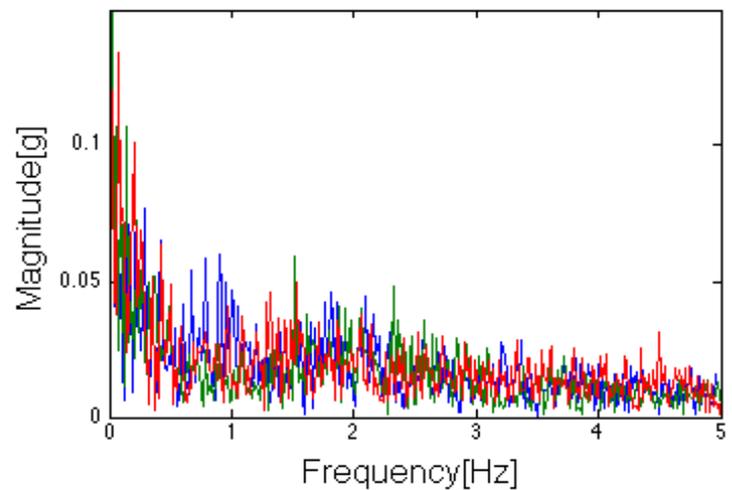
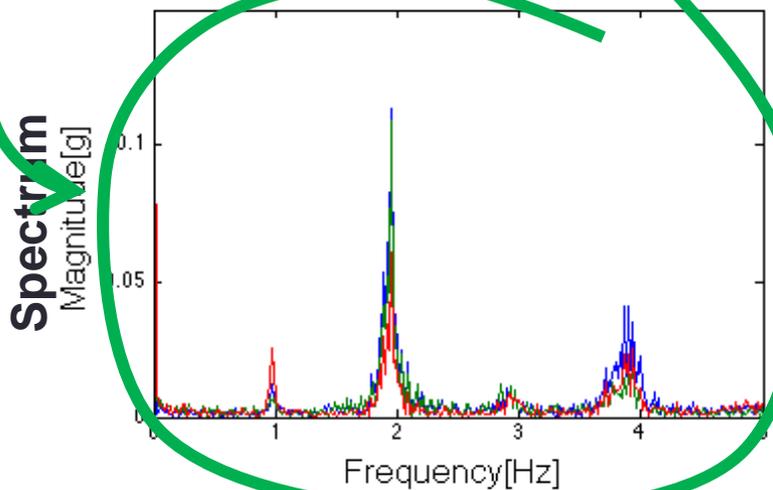
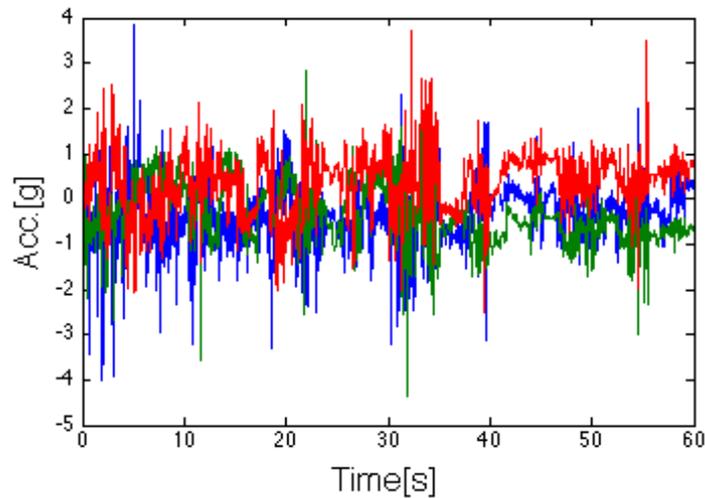


Frequency analysis

Walking (quasi-periodic)



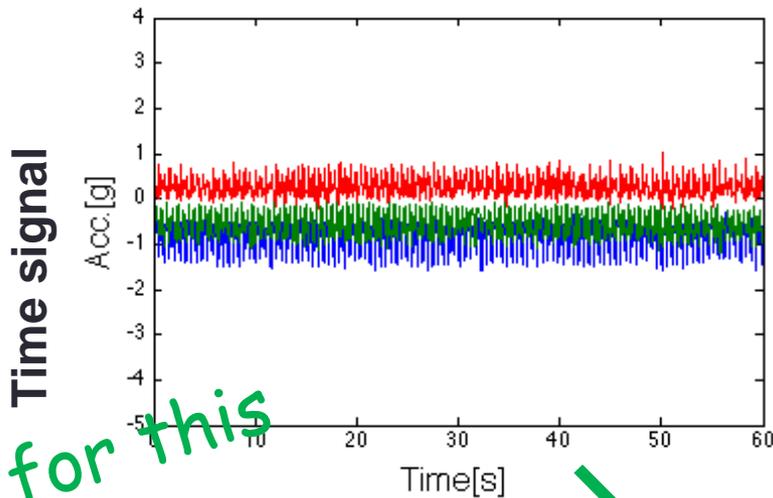
Another activity (non-periodic)



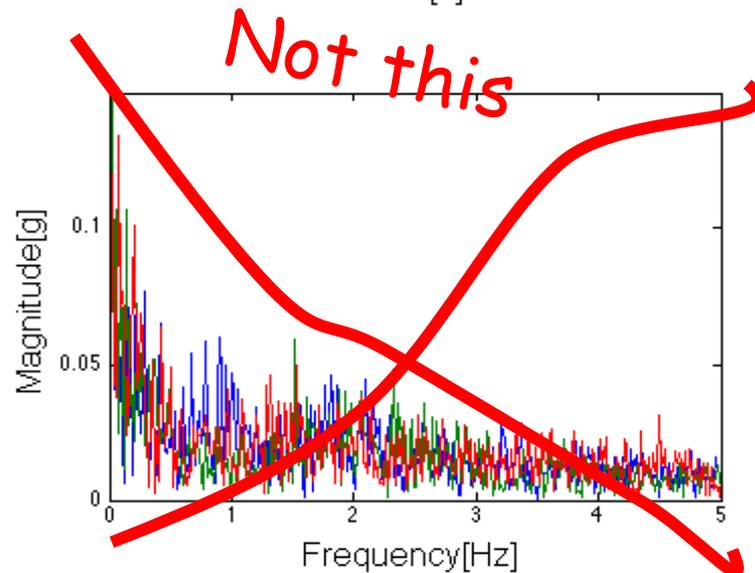
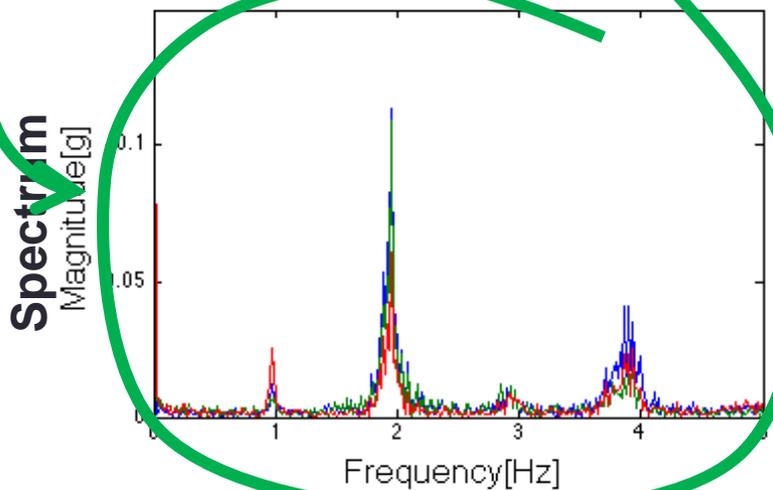
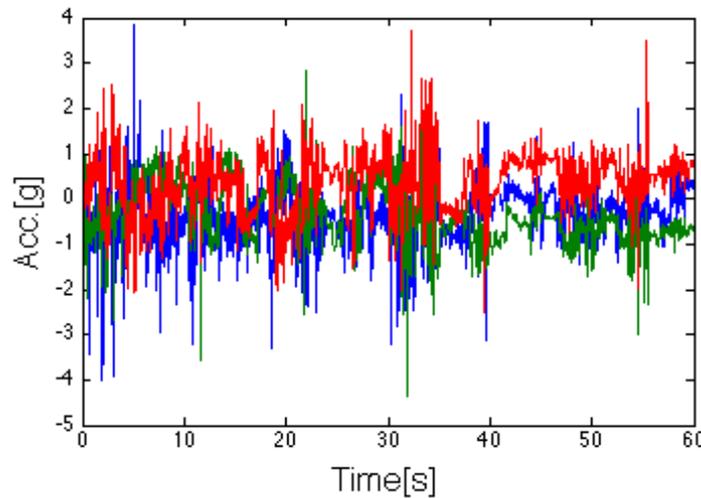
Look for this

Frequency analysis

Walking (quasi-periodic)



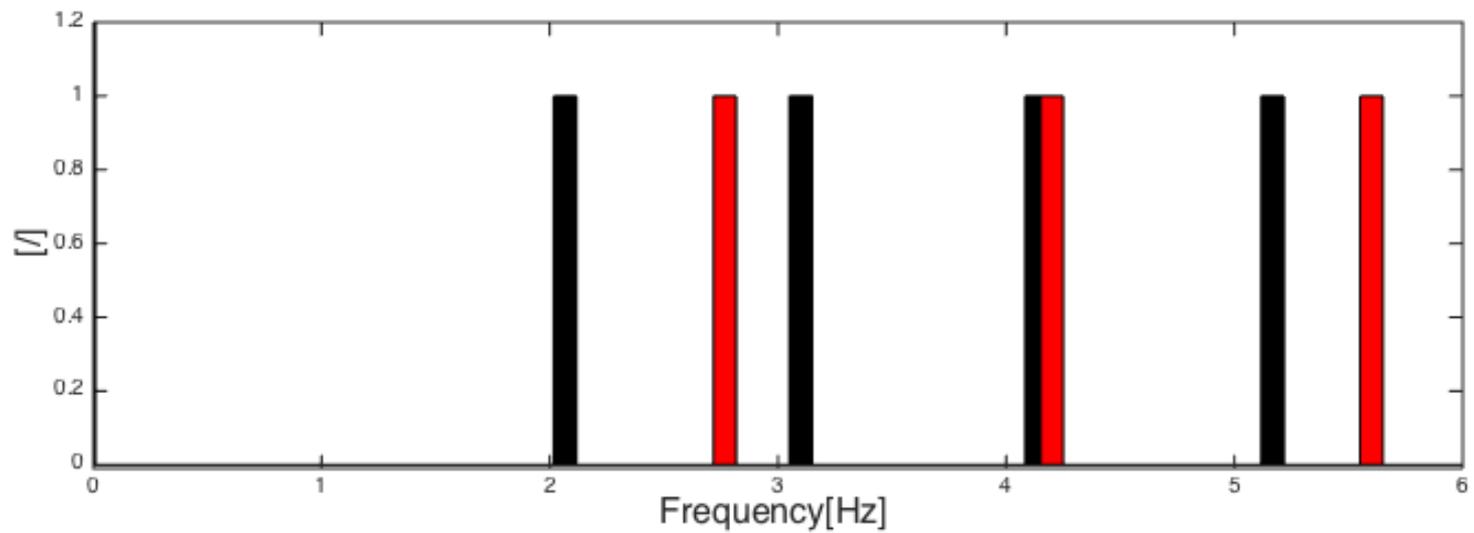
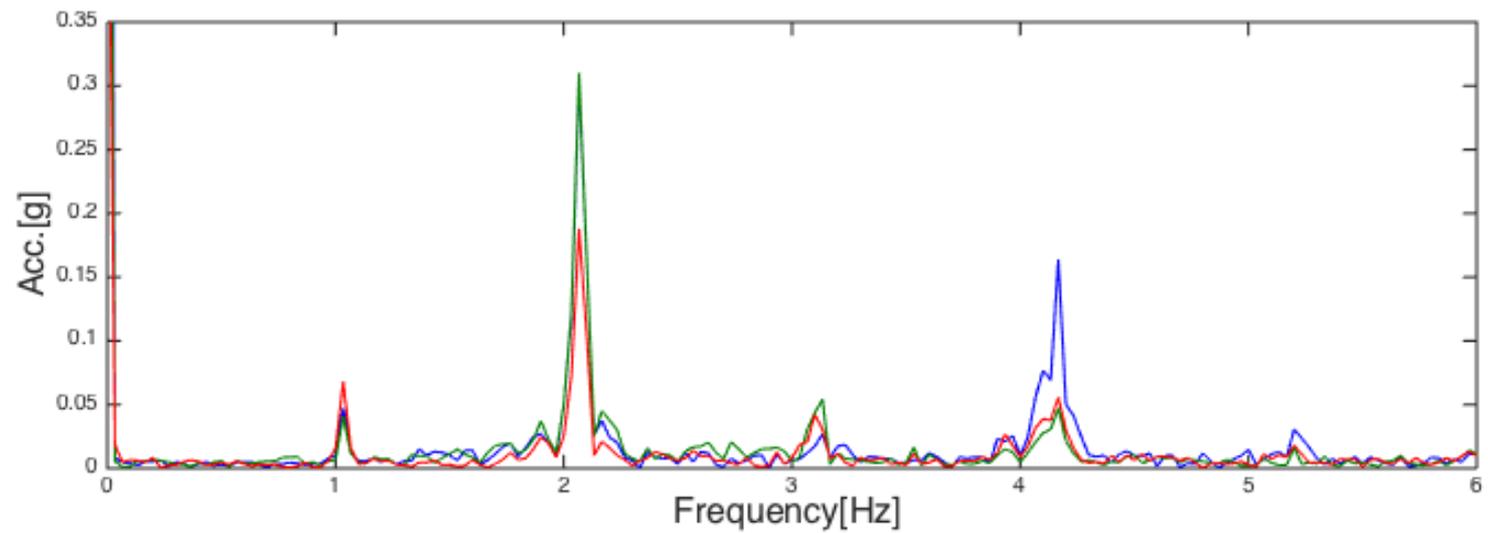
Another activity (non-periodic)



Look for this

Details of the method

1. Short-time Fourier Transform resulting in a spectrum
2. Comb function defined over discrete frequencies
3. Computation of the partial area under the spectrum
4. Ratio of the partial area to the total under the spectrum
5. Walking indicator when the ratio in 4. exceeds a threshold τ
6. Estimate characteristics of walking:
 - a. IWF (instantaneous walking frequency)
 - b. VM (vector magnitude)



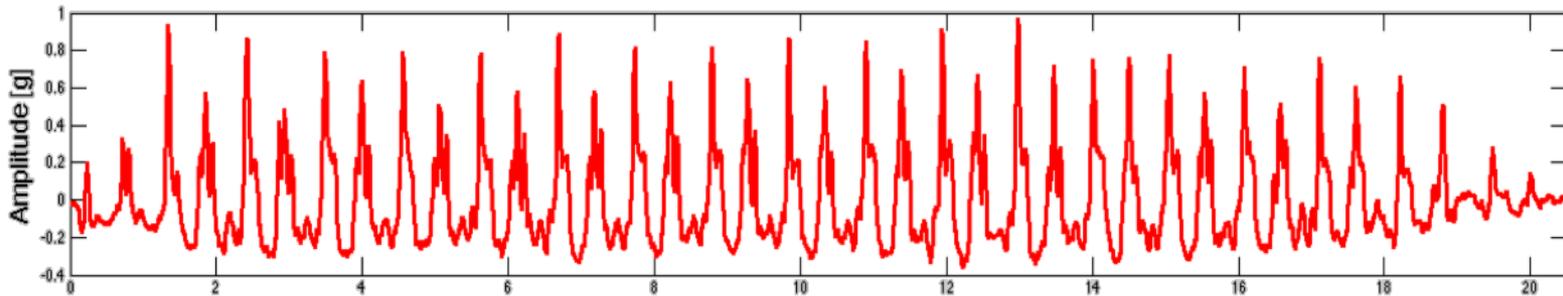
Features of walking

For example

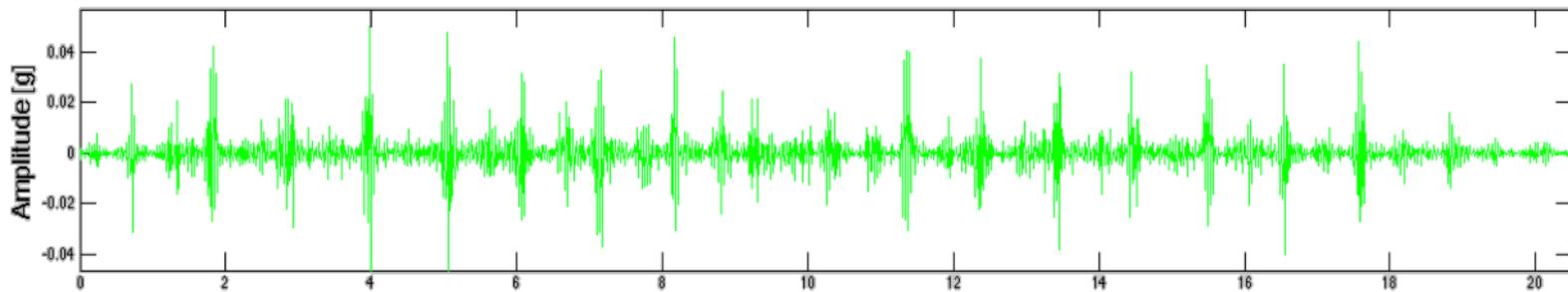
- Can we find within-person differences (e.g. healthy state vs. impaired state)?
- Can we differentiate between different people?
- Can we tell you how old you are based on the features of your walk?

Characterization of walking

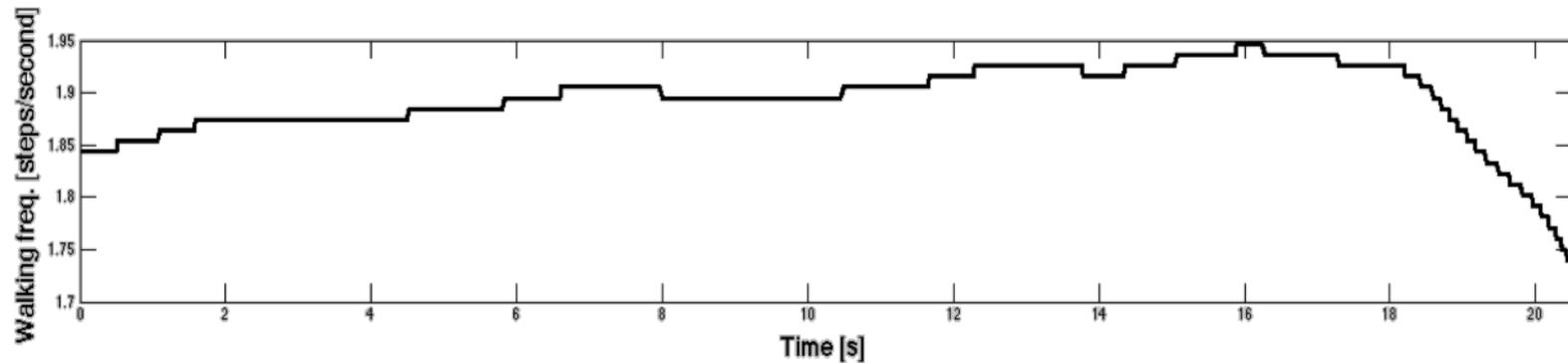
Stride
energy



Stomp
energy



Walking
frequency -
instantaneous

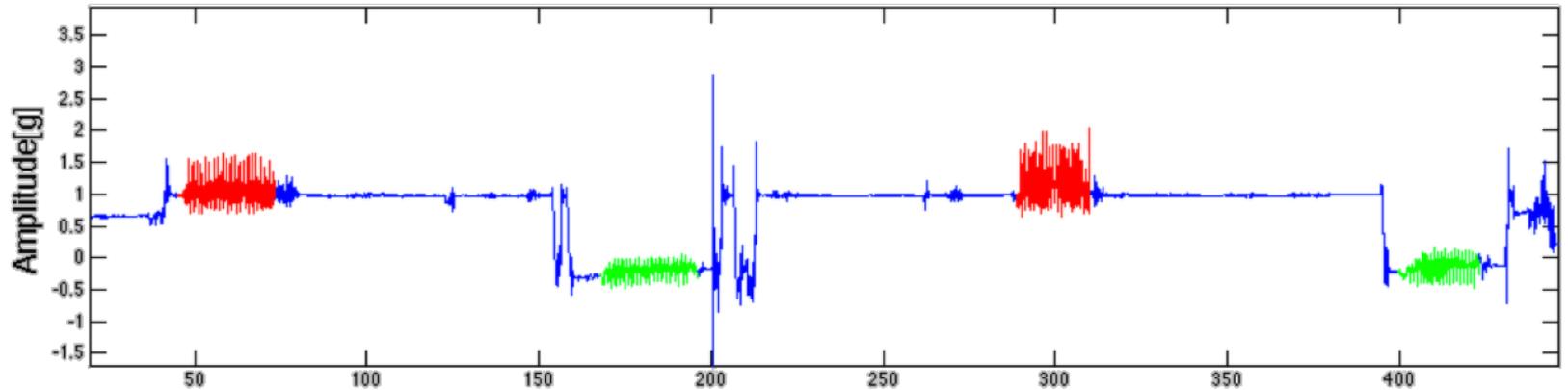


DECOs example – 20m walk

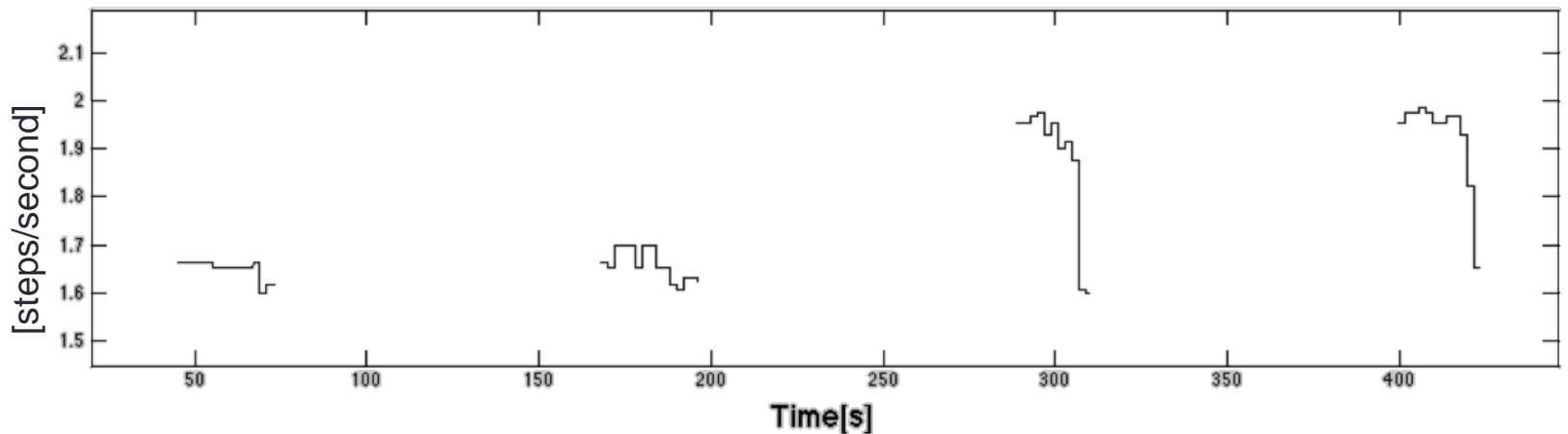
■ Walk (swing)

■ Walk (no swing)

Detection results



Walking frequency



DECOS experiment - 400m fast walk

N=43 elderly subjects

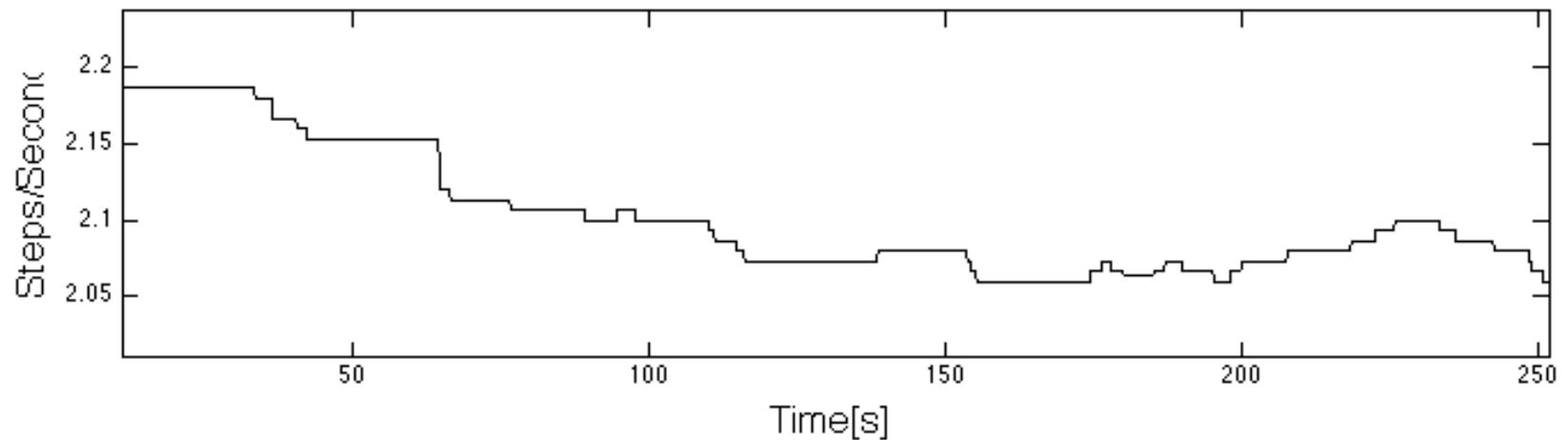
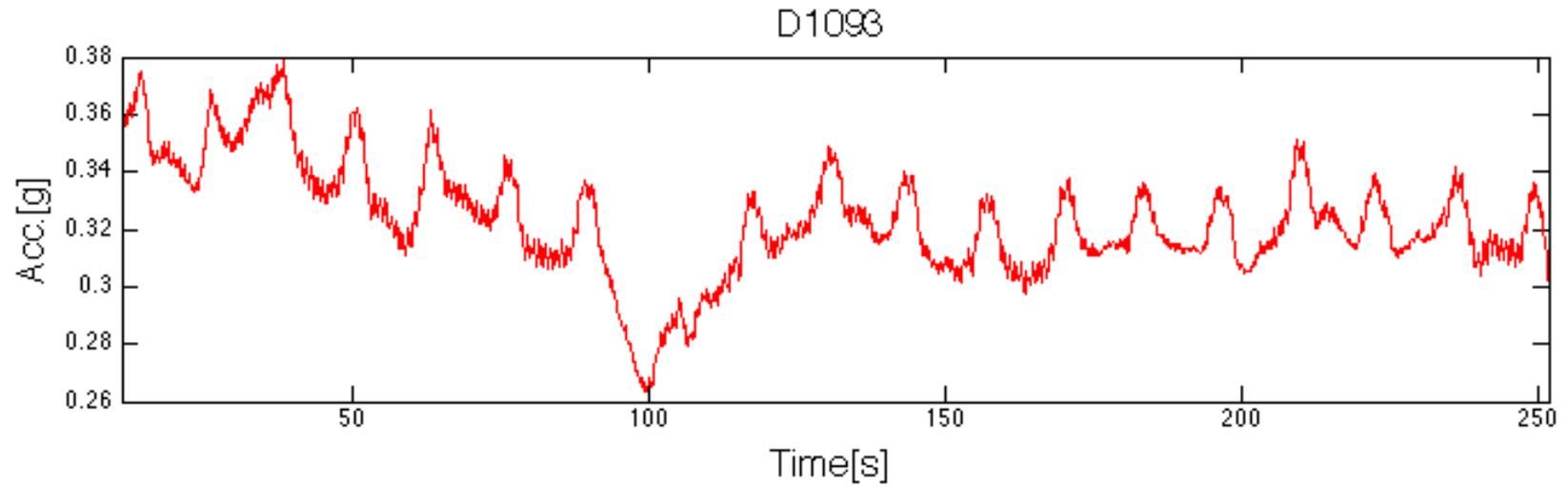
	Min	Q1	Median	Q3	Max
Age	70.3	74.7	79.1	84.3	92.3

Sex 22 Females, 21 Males

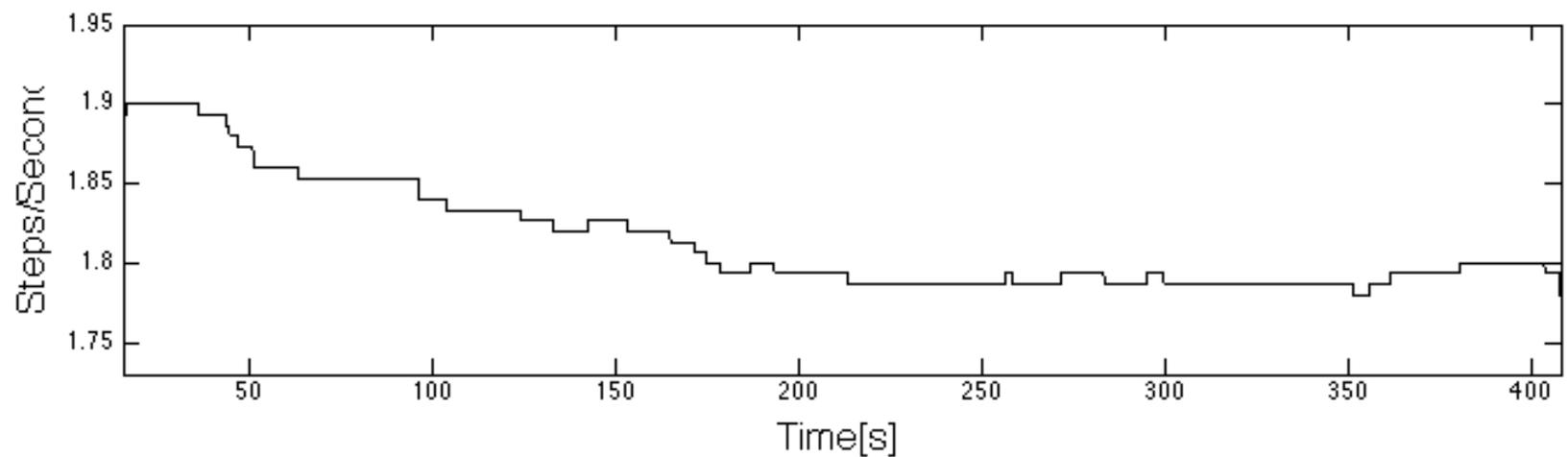
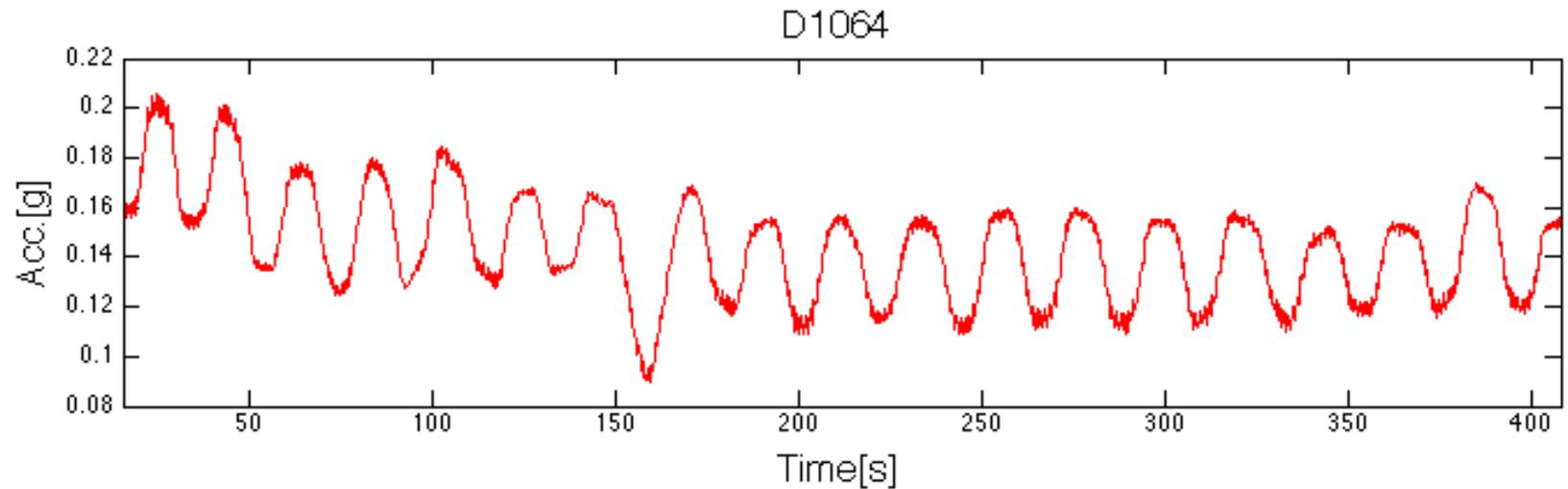
Hypothesis:

Features of 400m fast walk are indicative of aging

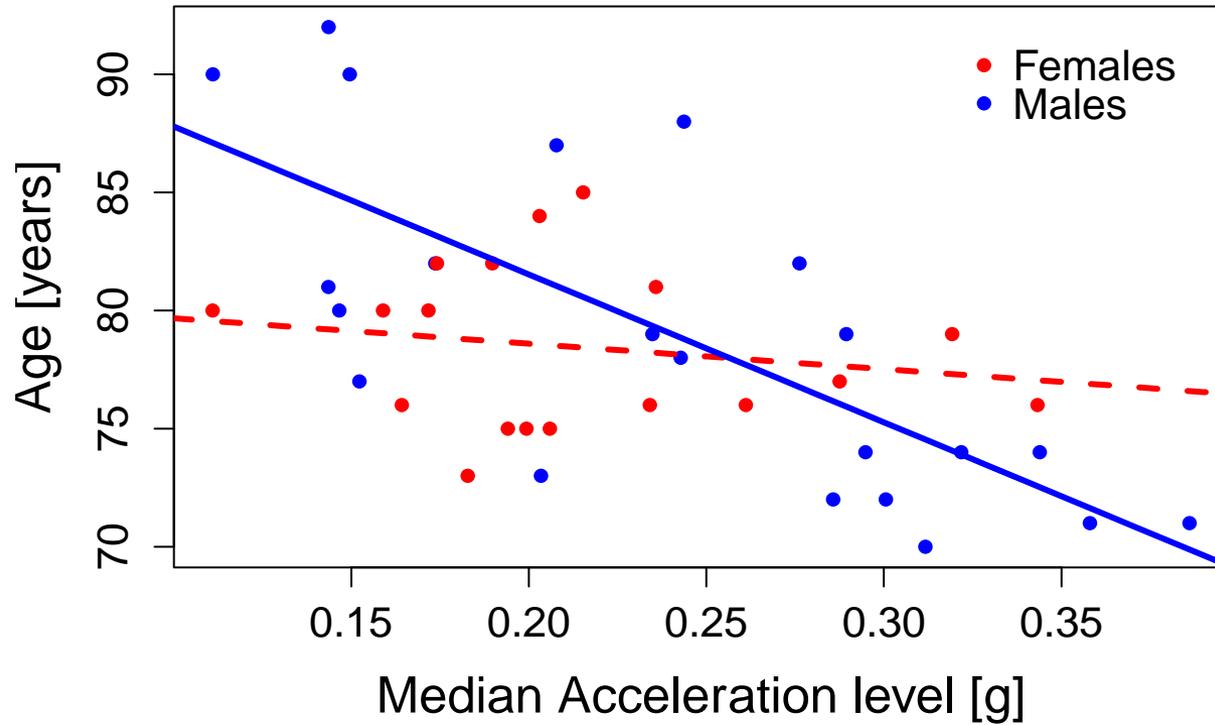
DECOS 400m: examples



DECOS 400m: examples



400m fast walk



**“In-the-wild” (free living)
experiment**

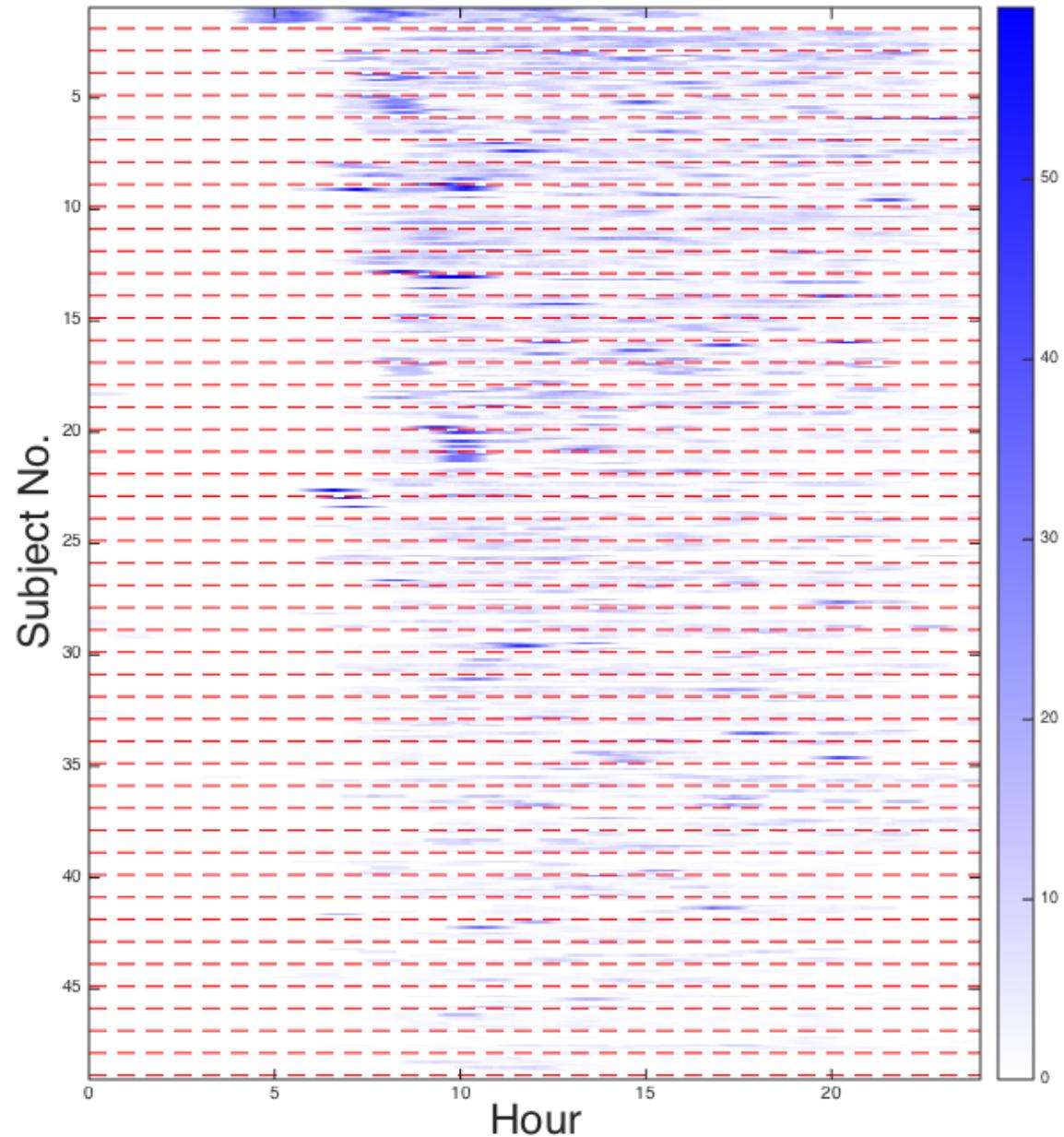
DECOS - free living experiment

- N = 49 elderly subjects
- Actigraph accelerometry data collected for 1 week
- 3 accelerometers (hip, right wrist and left wrist)
- DATA analyzed from the “hip” measurements

Major questions

- What is the total walking time per person within 1 week?
- Is walking time associated with age?

Walking minutes
per hour
estimated from
the 7-day
“in-the-wild”
data



Free living experiment

Factors associated with older AGE:

- ↓ Walking acceleration per minute
- ↓ Total time of walking
- ↓ Time of peak walking intensity

Summary

- Objective definition of physical activity
- Ability to extract walking information from raw accelerometry signal
- Methods are based on **universal** principles (frequency analysis approach)
- Characterization of walking characteristics
- Preliminary results associating features of walking and physical characteristics

Collaborators

Indiana University

- Marcin Straczekiewicz (Biostatistics - postdoc)

Johns Hopkins School of Public Health

- Jacek Urbanek (Biostatistics)
- Ciprian Crainiceanu (Biostatistics)
- Vadim Zipunnikov (Biostatistics)
- Jennifer Schrack (Epidemiology)

National Institute of Aging

- Tamara Harris

University of Pittsburgh

- Nancy Glynn (Epidemiology)

References

- Urbanek JK, Harezlak J, Glynn NW, Harris T, Crainiceanu C, Zipunnikov V. Stride variability measures derived from wrist- and hip-worn accelerometers. *Gait Posture*. 2016 Nov 30;52:217-223.
- Straczekiewicz M, Urbanek JK, Fadel WF, Crainiceanu CM, Harezlak J. Automatic car driving detection using raw accelerometry data. *Physiological Measurement* 2016. 37 (10), 1757-1769.
- Urbanek JK, Zipunnikov V, Harris TB, Fadel W, Glynn NW, Koster A, Caserotti P, Crainiceanu CM, Harezlak J. Prediction of sustained harmonic walking in the free-living environment using raw accelerometry data. *Physiol Meas*. 2018 Jan 12.
- Urbanek JK, Zipunnikov V, Harris T, Crainiceanu C, Harezlak J, Glynn NW. Validation of Gait Characteristics Extracted From Raw Accelerometry During Walking Against Measures of Physical Function, Mobility, Fatigability, and Fitness. *J Gerontol A Biol Sci Med Sci*. 2018 Apr 17;73(5):676-681

Thank you

