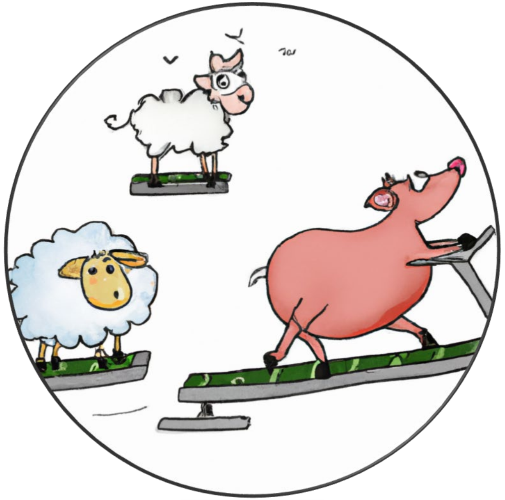
Automated real-time activity monitoring in animal experiments with various livestock species

Harmen P. Doekes, R. de Jong, I. Adriaens, N. Stockhofe-Zurwieden



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EAAP session 56, 3-9-2024

Acknowledgements

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Biotechnicians

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Animal experiments in the EU

- In EU, 8 million animals are used annually for animal experiments*
- >400k 'domestic fowl', >120k 'farm mammals' and 10k cats & dogs

Species	Number of animals	Percentage
Mice	4010766	47.86%
Salmon, trout, chars and graylings	1289139	15.38%
Other fish	691587	8.25%
Rats	625777	7.47%
Domestic fowl	417903	4.99%
Rabbits	372239	4.44%
Zebra fish	362449	4.33%
Sea bass	116706	1.39%
Pigs	86953	1.04%
Guinea-Pigs	85167	1.02%
Other birds	80531	0.96%
Guppy, swordtail, molly, platy	78388	0.94%
Hamsters (Syrian)	21613	0.26%
Cattle	21434	0.26%
Turkey	18577	0.22%
Sheep	15909	0.19%

Etc.

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**ALURES: EU statistics database, 2023*

Typical set-up of an (infectious disease) experiment

- Timeline:

- Treatment and control groups
- Especially in weeks after treatment, various parameters are measured

Monitoring behaviour in animal experiments

Why?

To monitor welfare

Refine studies

To better understand effect of treatment

Improve studies

How?

Traditionally, caretaker observations

(bi-)daily snapshots

Increasingly, also **sensor technologies**

Continuous
Objective
Automated
Simultaneous

Many sensor technologies out there, but not all appropriate for our setting of interest...

Aim

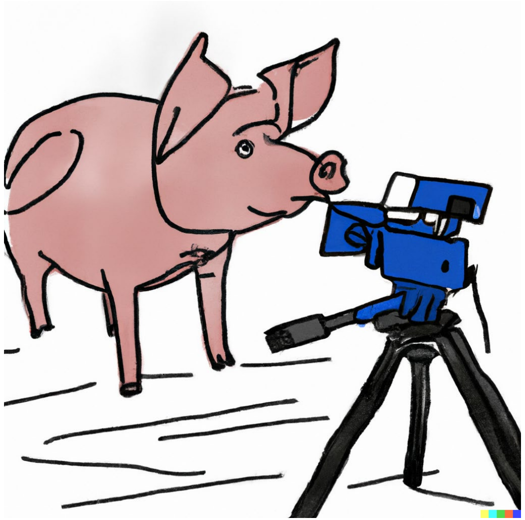
Explore technologies and **develop a tool** for automated and real-time monitoring of individual behaviour, particularly activity, in (livestock) experiments

Conditions & requirements

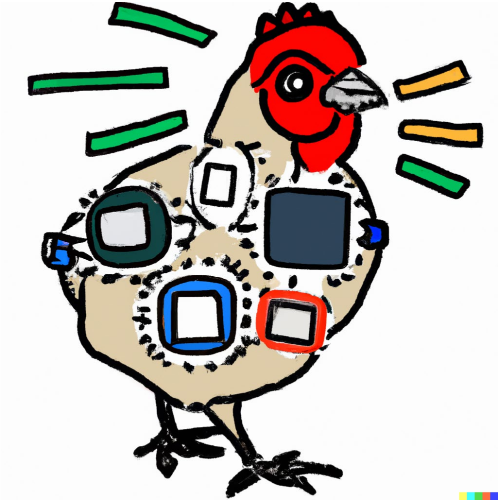
- Multiple (non-rodent) species
- Group housing
- Biosafety levels 2 & 3
- Easy installation
- Duration: 4-8 weeks
- Minimise handling & impact
- Real-time
- Affordable & re-usable

Two types of technologies

Computer vision (CV)

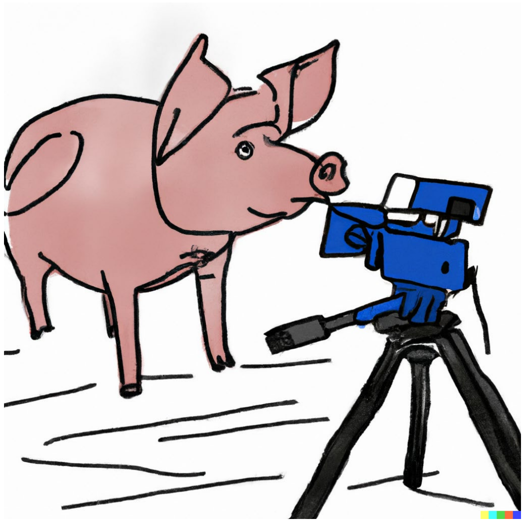


Body worn sensors (BWS)



Two types of technologies

Computer vision (CV)



Body worn sensors (BWS)

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CV example (I): frame differencing

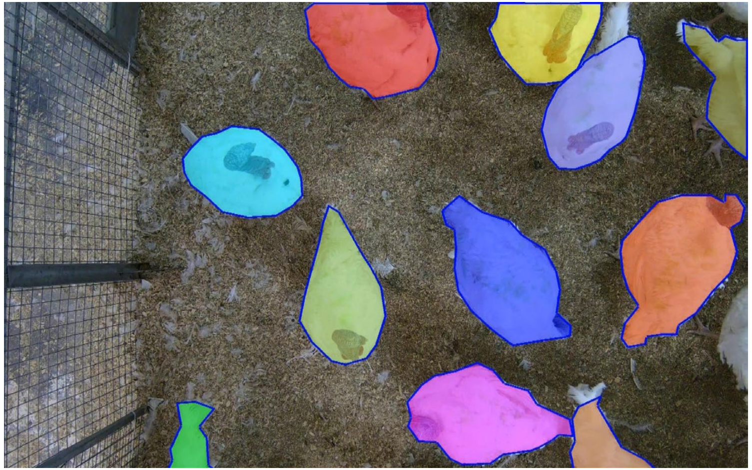
- Pros: simple, cheap, no impact on animal
- Cons: background dependence, no individual data

Interested in results?

Gerhards et al. (2023), doi: 10.1128/spectrum.02553-22

CV example (II): individual detection and tracking with e.g. neural networks

- Pros: individual data, no impact on animal
- Cons: large effort to train and run, challenges with a.o. (re-)identification, occlusion and multi-camera tracking*

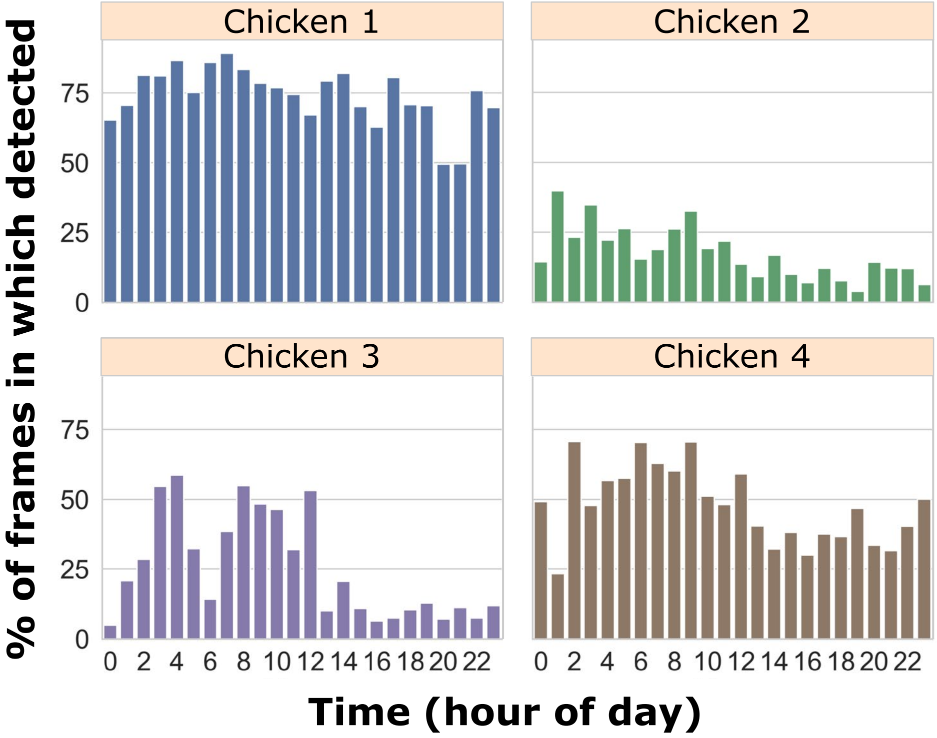


*Wang et al. (2024), EAAP book of abstracts p. 403

CV example (III): Aruco markers

- Pros: individual data, open-source detection tools (no annotation)
- Cons: attachment, visibility (e.g. dirt/feathers), motion blur

Variation in Aruco detections across animals and time



In cases of few detections, animal could be:

1. Inactive in occluded area;

OR

2. Active and not detected due to motion blur, occlusion due to feathers, etc.

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CV example (IV): Aruco & frame differencing

- Combine approaches to better assess specific behaviours
- E.g. 4 days after *T. gondii* infection, rams halved their time drinking

Doekes et al. (2024), doi: 10.3390/ani14131908

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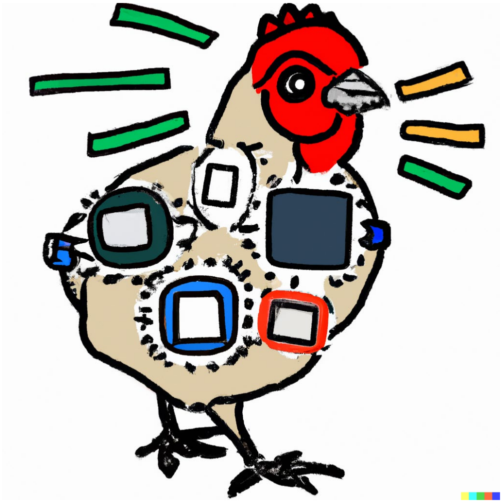
Two types of technologies

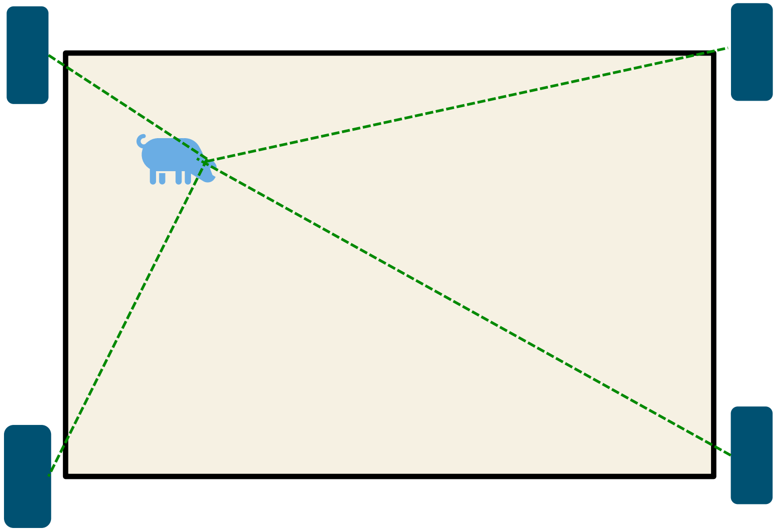
Computer vision (CV)

Body worn sensors (BWS)



BWS example (I): ultra-wideband

- Pros: individual location data
- Cons: sensor size (~25 g; for animals > 500 grams), laborious installation, error of 20-30 cm, hardware issues → missing data



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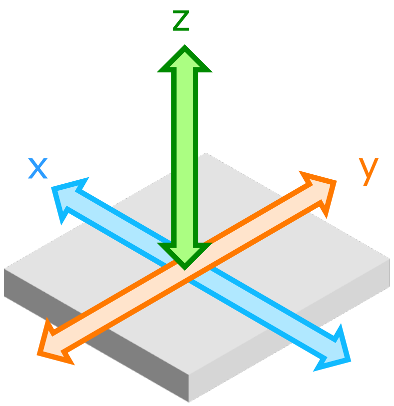
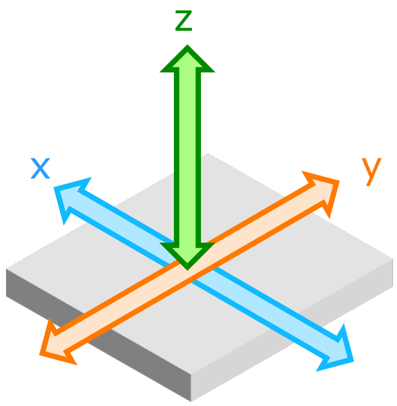
Noldus

BWS example (II): accelerometers

- Pros: small sensor size (e.g. 10g), reliable data stream, relatively simple installation and data processing, affordable
- Cons: acceleration is an indirect measurement of activity/behaviour



Accelerometers



- Acceleration in x, y and z

- Acceleration consist of 2 components:
  1) Static: gravity, perpendicular to earth
  2) Dynamic: resulting from movement

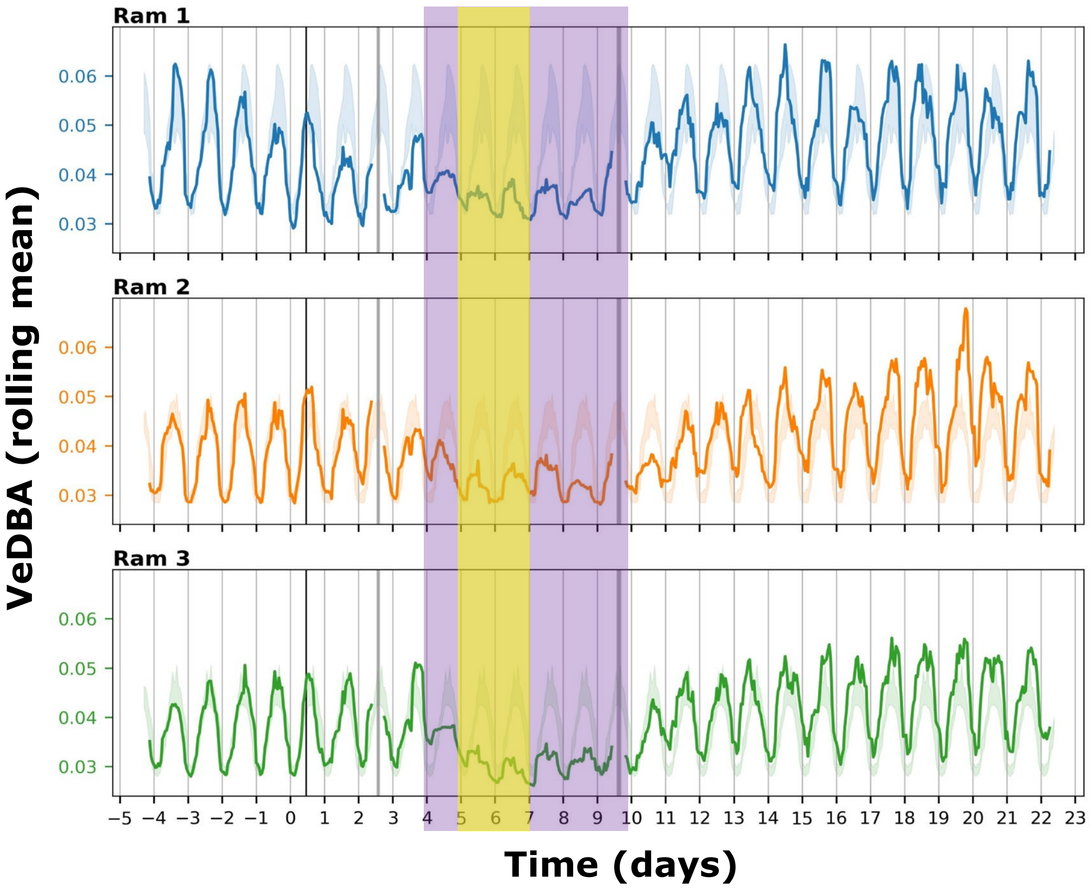
- Vectorial Dynamic Body acceleration ***(VeDBA)***:

$$VeDBA_i = \sqrt{(x_i - \overline{x_i})^2 + (y_i - \overline{y_i})^2 + (z_i - \overline{z_i})^2}$$

Example: activity of sheep infected with *T. gondii*

Biotechnicians only recorded a decreased activity in day 5 & 6 (!)

Doekes et al. (2024), doi: 10.3390/ani14131908



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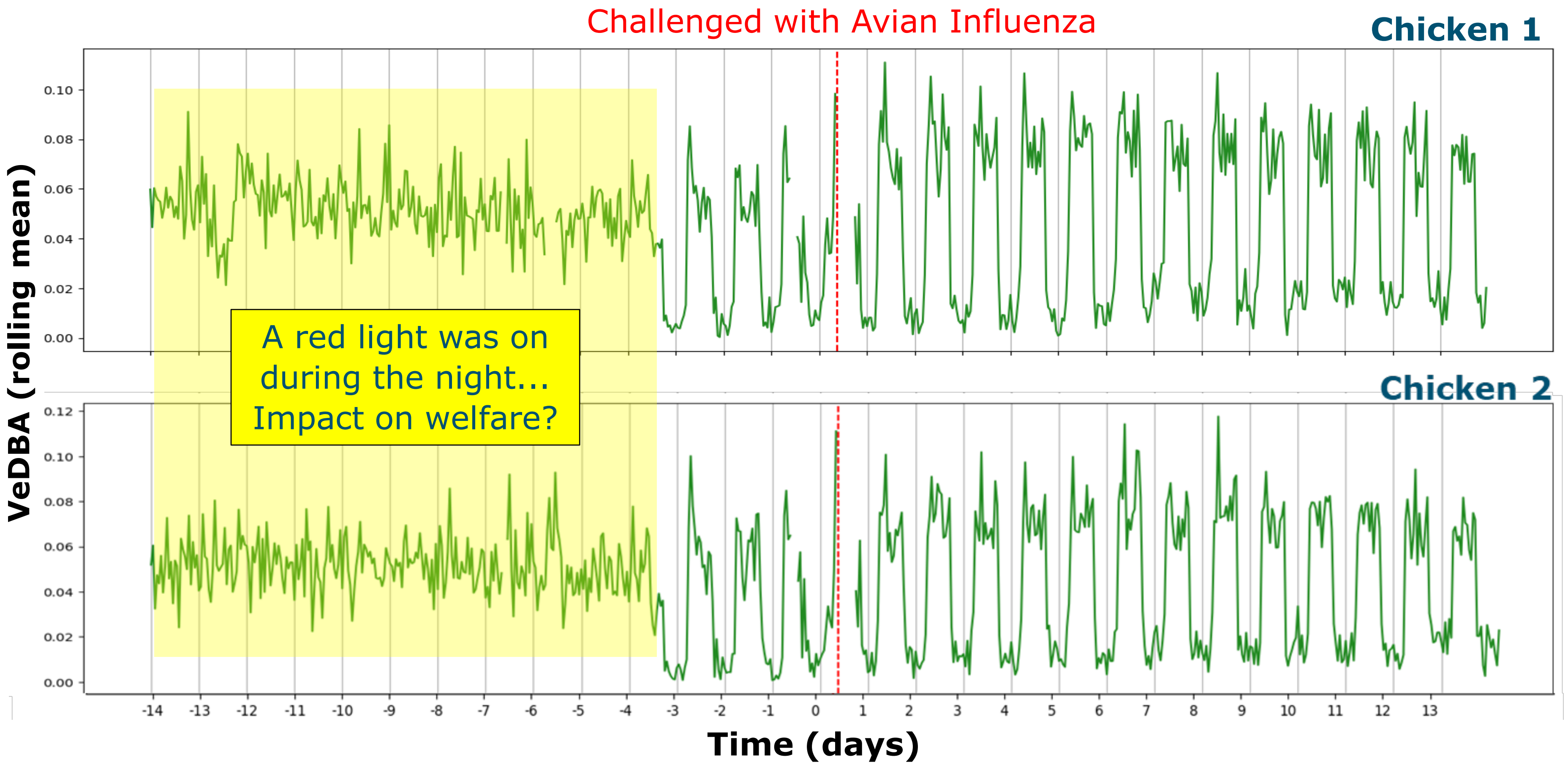
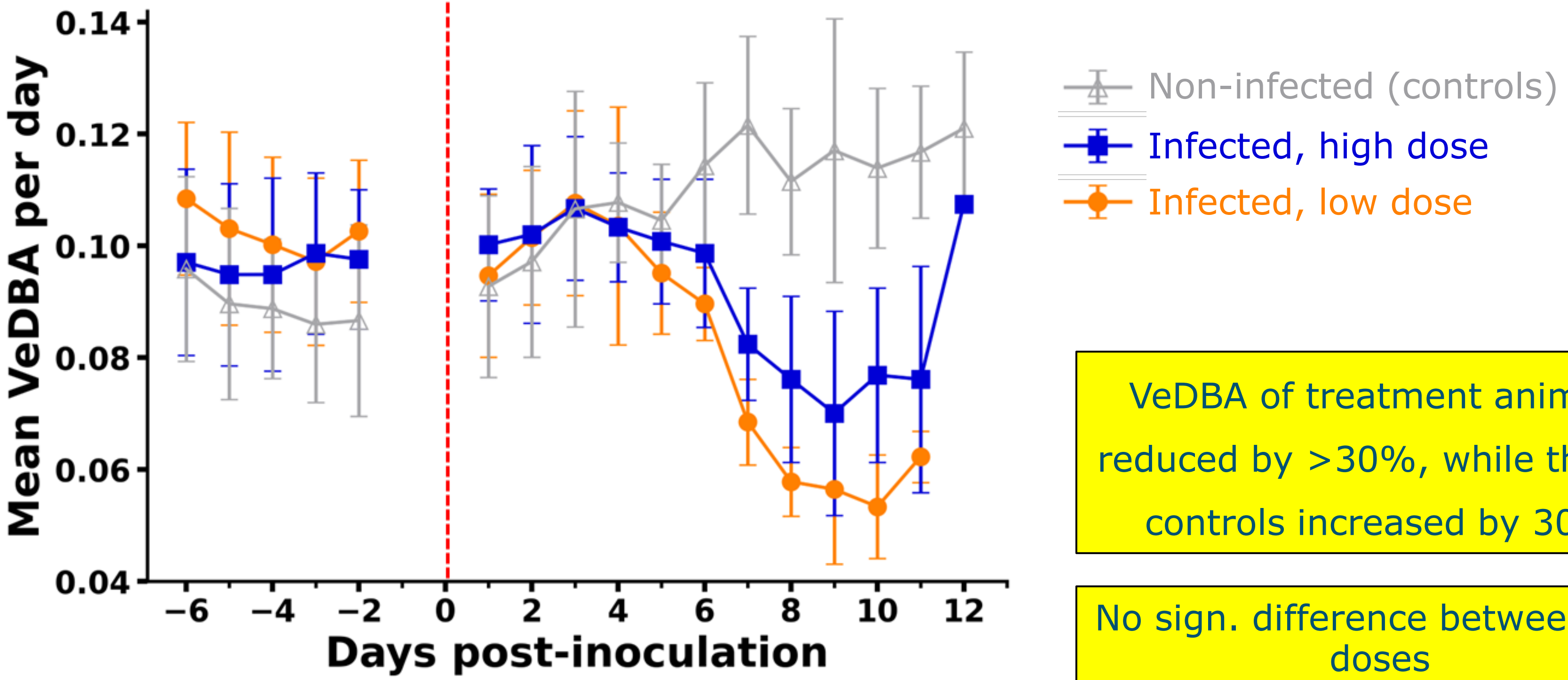
Example: environmental influences



Example: comparing infected and non-infected

Infection of sheep with Bluetongue virus



VeDBA of treatment animals reduced by >30%, while that of controls increased by 30%

No sign. difference between two doses

RAMSMART: a tool for **R**eal-time, **A**utomated and **M**ulti-**S**pecies **M**onitoring of animal **A**ctivity in **R**esearch **T**rials

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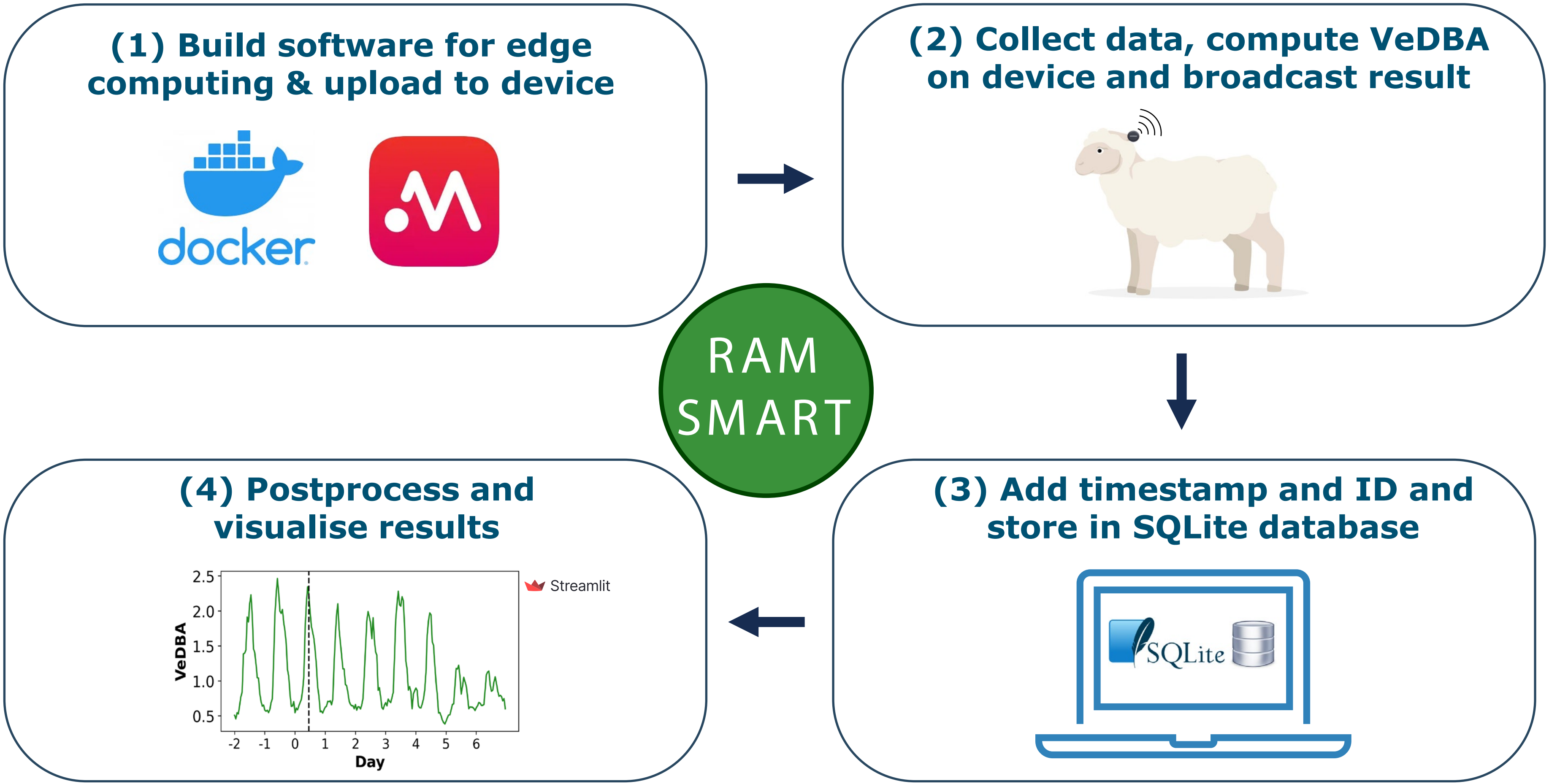
Specs of the device

What?	Specification
Sensors	Accelerometer (up to ±16g), gyroscope and magnetometer, 12.5 to 833 Hz. *flexibility ☺* Heart rate and non-medical ECG.
Size	Diameter 36.6 mm Thickness: 10.6 mm
Weight	10 gram *"5% rule" → for animals ≥200 grams ☺*
Battery	CR2025 coin cell
Data transmission	BLE (2.4GHz) directly to a nearby laptop
Edge computing	Yes *no need to transmit raw data → battery life ☺*
Waterproofness	Water resistant to 30m
Costs	~ € 100 per sensor ~ € 0,60 per battery

affordable & re-usable ☺



(1) Build software for edge computing & upload to device
docker
(2) Collect data, compute VeDBA on device and broadcast result
RAM SMART
(3) Add timestamp and ID and store in SQLite database
SQLite
(4) Postprocess and visualise results
Streamlit
VeDBA
2.5
2.0
1.5
1.0
0.5
-2
-1
0
1
2
3
4
5
6
Day

Example visualisation

How long can we monitor?

- Depends on frequency of sampling, frequency of updating VeDBA, and frequency of broadcasting data packages

- Current settings:
  - ➢ Sampling at 13 Hz
  - ➢ Update VeDBA every minute
  - ➢ Broadcast at 4 Hz

Battery life >8 weeks

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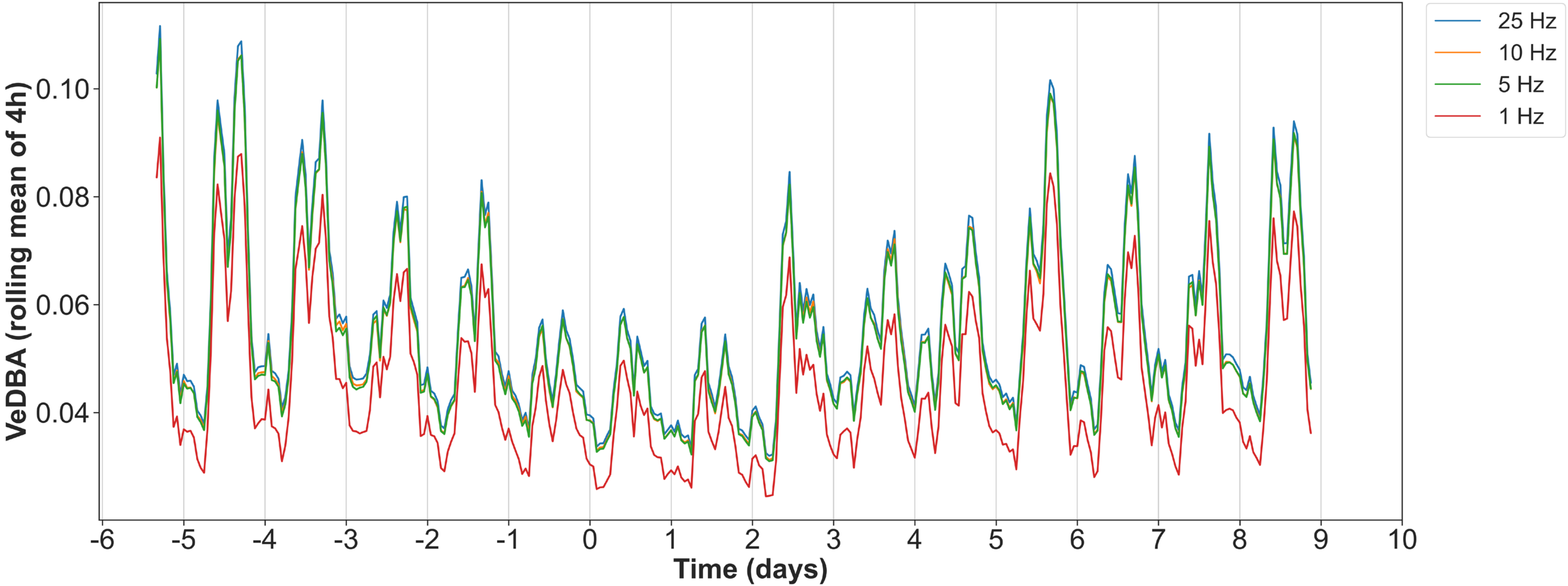
How frequent should we sample?



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Lower frequency → slightly lower VeDBA, but patterns remain similar

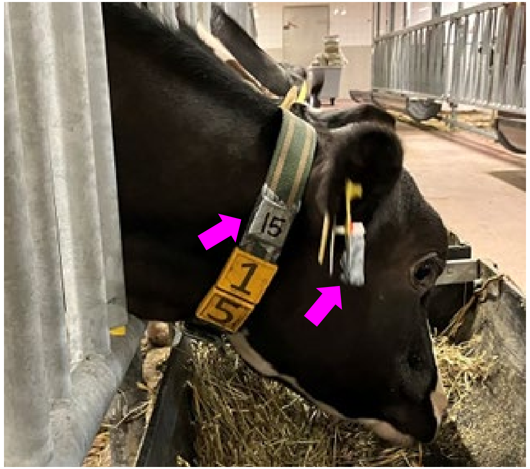
Similar results in cattle, chicken and sheep

Does it matter how we attach the accelerometer?

Sheep

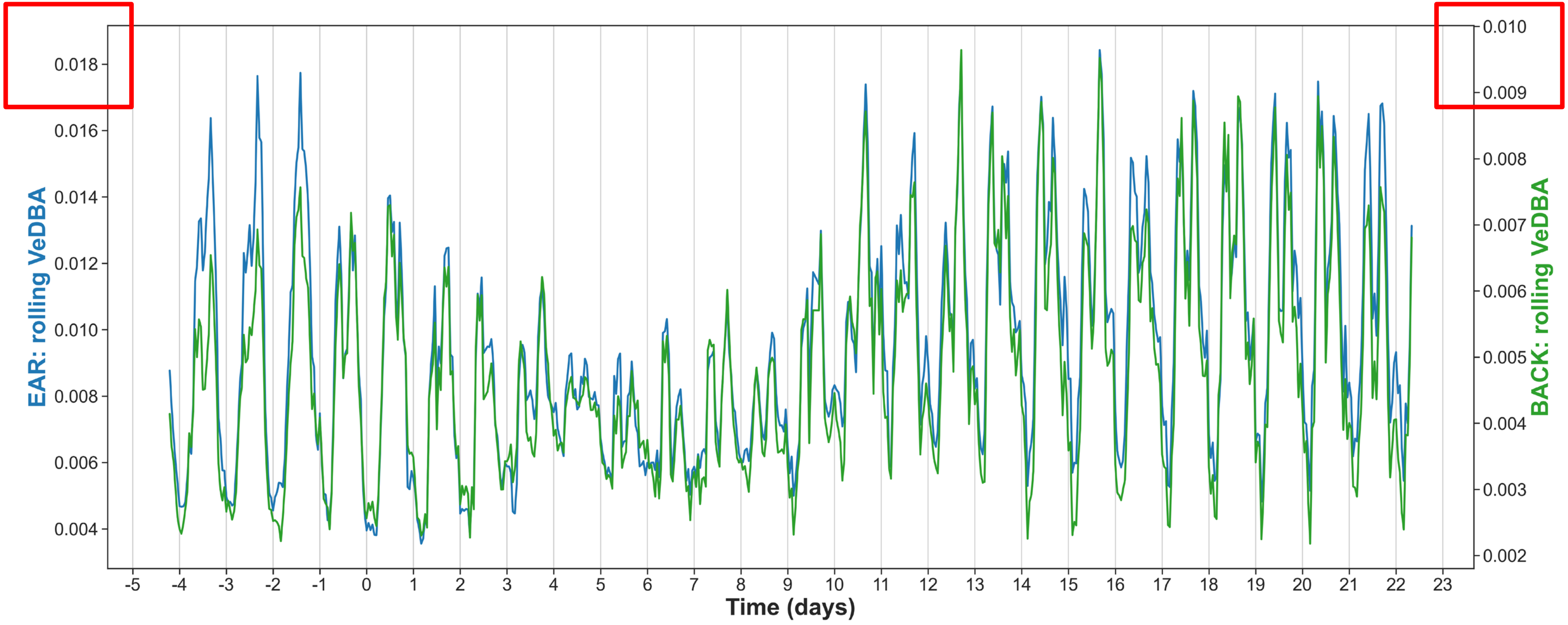
BACK vs EAR?

Calves



LEG vs BACK vs EAR?

Effect of accelerometer position in a sheep



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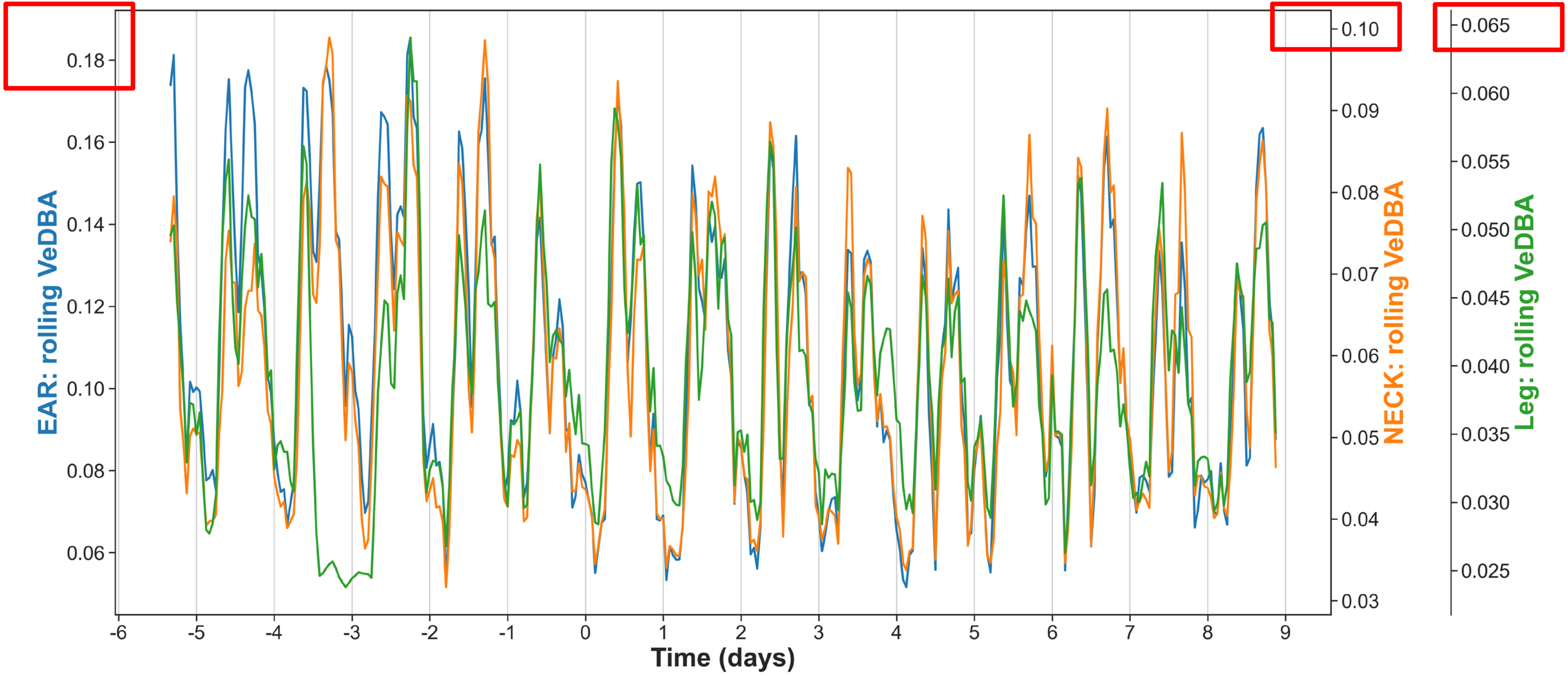
BACK < EAR, but patterns similar

Effect of accelerometer position in a calf



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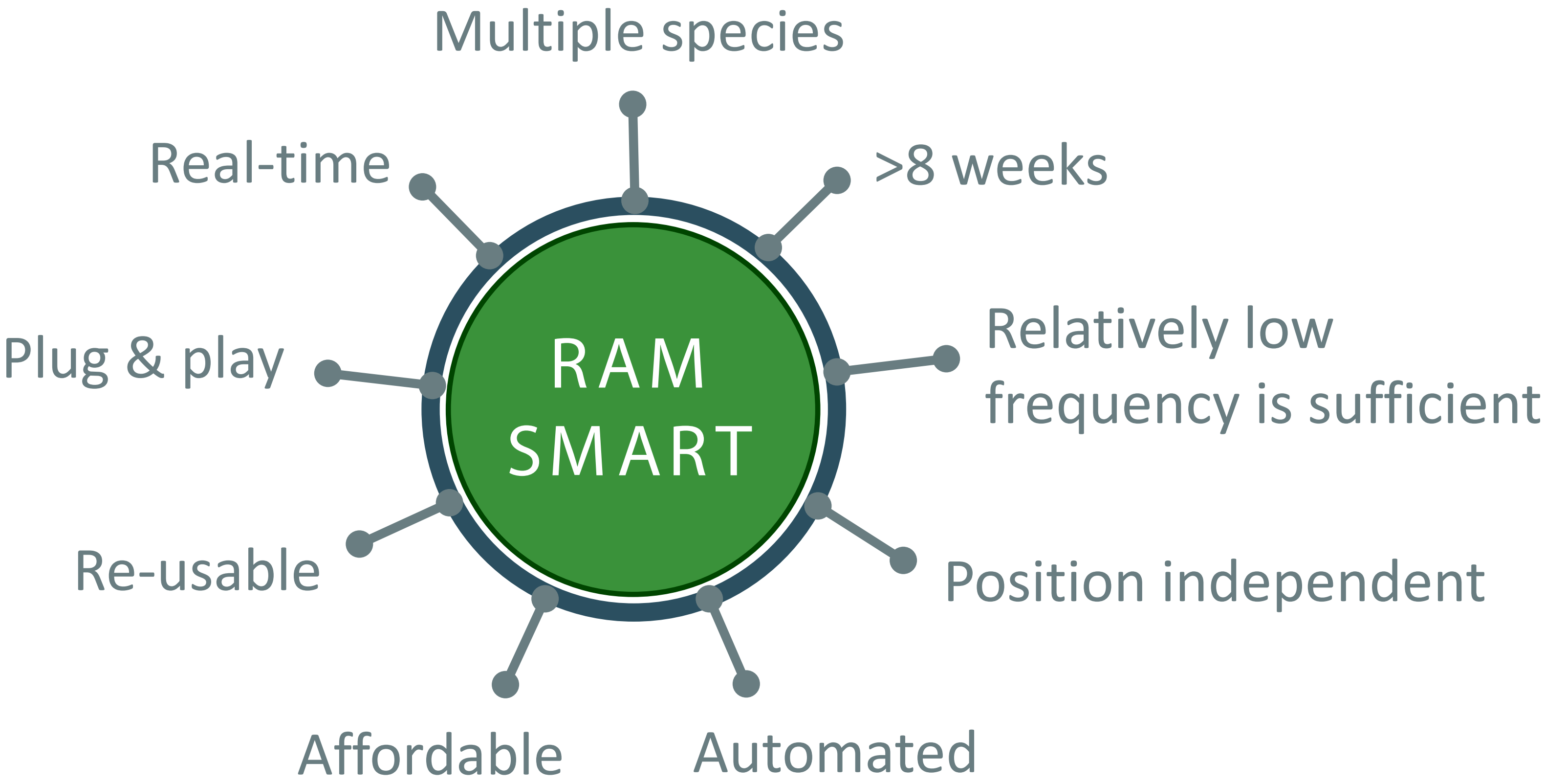
LEG < NECK < EAR, but patterns fairly similar

Conclusions

- Sensor-based behavioural monitoring has added value in animal experiments:
  - To earlier detect deviations and quantify their severeness
  - To detect (unintended) environmental influences
- But always be aware of the pitfalls of each approach
- An accelerometery-based tool ticks most of our boxes



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Extra slides

VeDBA and oxygen consumption

- ODBA and VeDBA correlate well with rate of oxygen consumption in treadmill tests, e.g. Qasem et al 2012

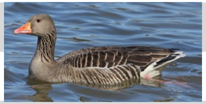
Humans

	Straight	Skewed
ODBA	$VO_2 = 1132.ODBA+615$ $r^2 = 0.915$	$VO_2 = 1466.ODBA+776$ $r^2 = 0.94$
VeDBA	$VO_2 = 1664.VeDBA+636$ $r^2 = 0.914$	$VO_2 = 1659.VeDBA+629$ $r^2 = 0.91$

doi:10.1371/journal.pone.0031187.t001

Various species






Species	*ODBA*	*VeDBA*
Chaetophractus villosus	0.9775	0.942
Myocastor coypus 1	0.9594	0.94
Myocastor coypus 2	0.7449	0.7019
Myocastor coypus 3	0.9473	0.9486
Myocastor coypus 4	0.8617	0.8568
Cairina moschata	0.9853	0.9841
Anser anser 1	0.9022	0.8904
Anser anser 2	0.9427	0.9242
Spheniscus magellanicus 1	0.975	0.9662
Spheniscus magellanicus 2	0.8979	0.811
Eudyptes chrysocome	0.9914	0.9957

doi:10.1371/journal.pone.00

Comparing activity of Aruco with VeDBA

- VeDBA of chickens is similar, but Aruco-distance for animal 5 is underestimated
- For both chickens, correlation between approaches is poor to moderate (0.44-0.66)