The role of precision technologies in beef cattle production

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CENTRAL CANADIAN VETERINARY CONFERENCE

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USASK.CA/WCVM

What, when and how?

- Monitoring animal location
- Monitoring animal activity
  - Grazing preference
  - Tail flick behaviour
  - Feed intake
- Pain assessment
- Temperament assessment
- Cognitive research
- Motivation state

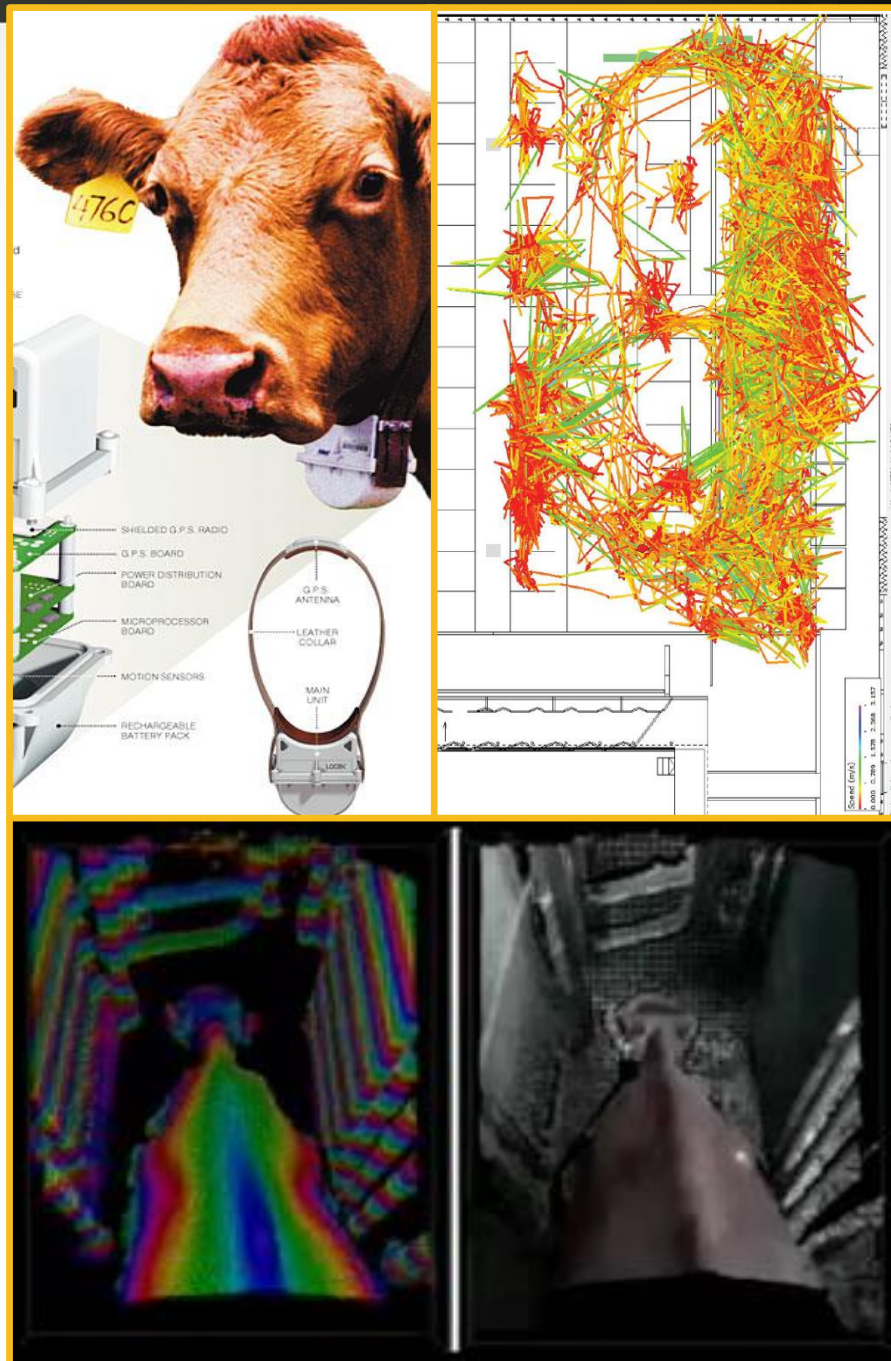
What to use and why?

- It needs to generate a return of the investment
- It needs to integrate with other technologies or day to day practices at the farm.
- It needs to help us accomplish goals we already have (technology is not the goal)

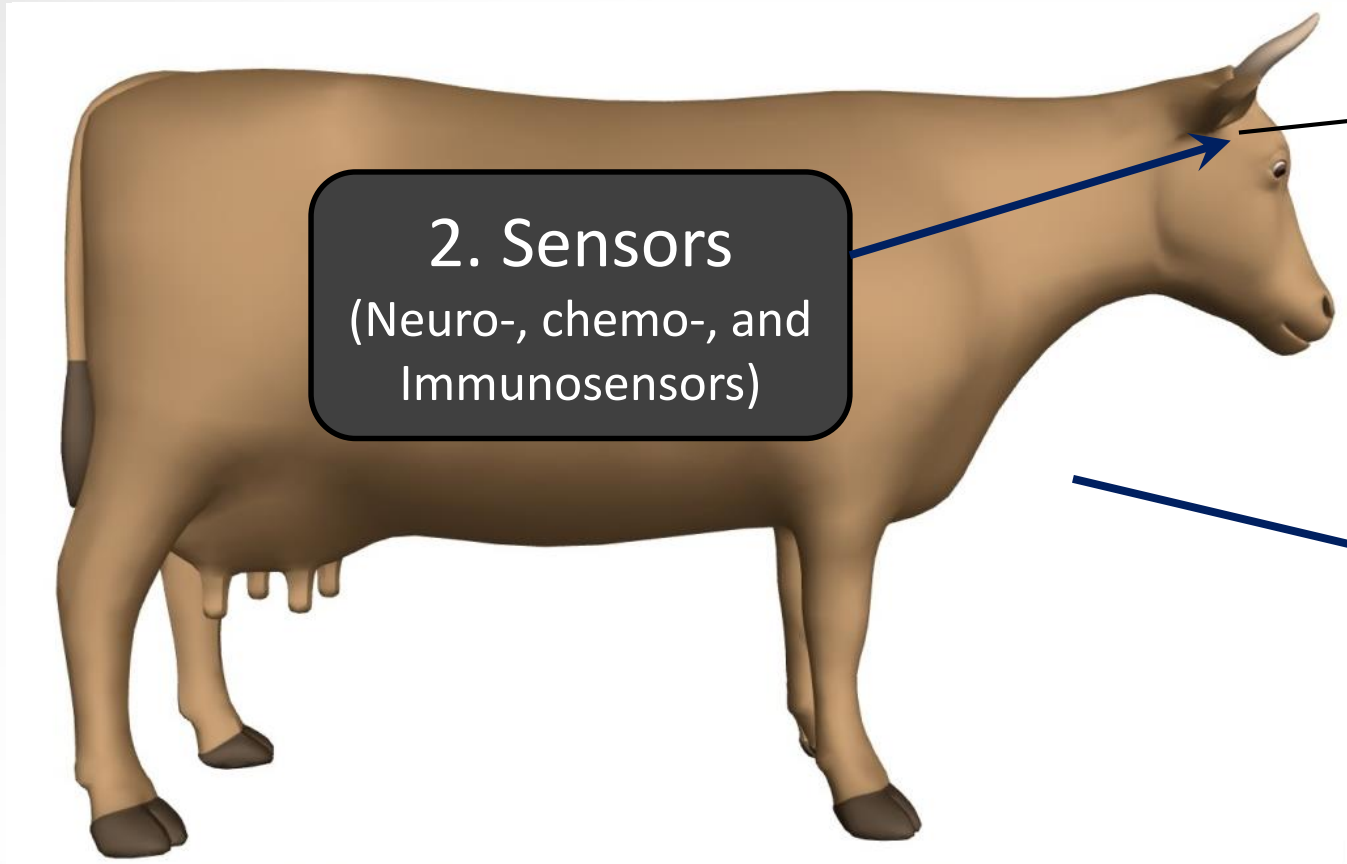
Precision technologies to phenotype livestock

To measure and manage herd variability at an individual level (including animal movement, activity, feed intake…)

- Early diagnostic of diseases (use and efficacy of antimicrobials)
- Resources exploitation
- Improved management strategies



A representation of stimulus processing



3. Perceptions (valence, salience, intensity, controllability and predictability)

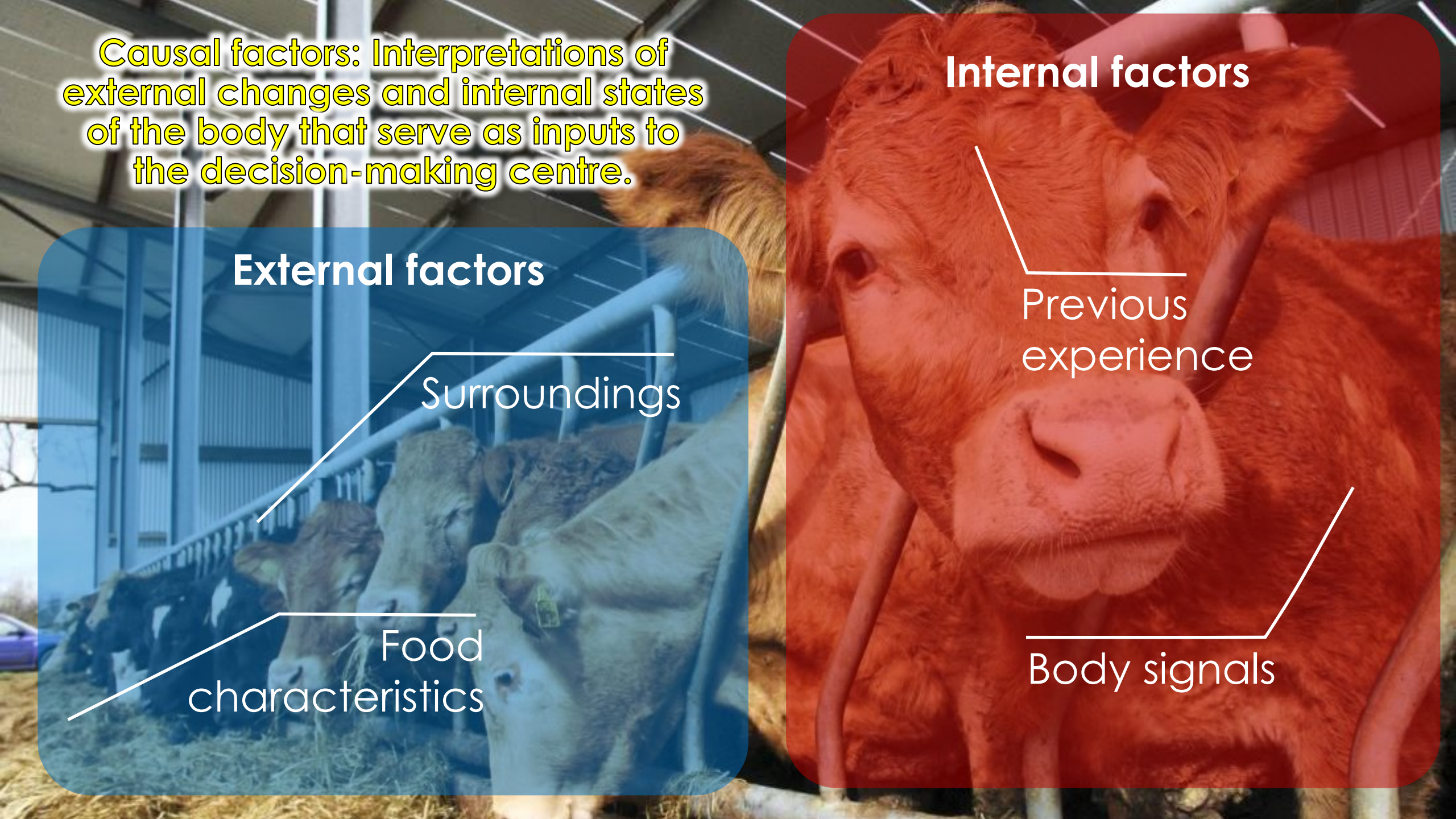
4. Affects (sensations, motivations, emotions, moods; valence and arousal)

2. Sensors (Neuro-, chemo-, and Immunosensors)

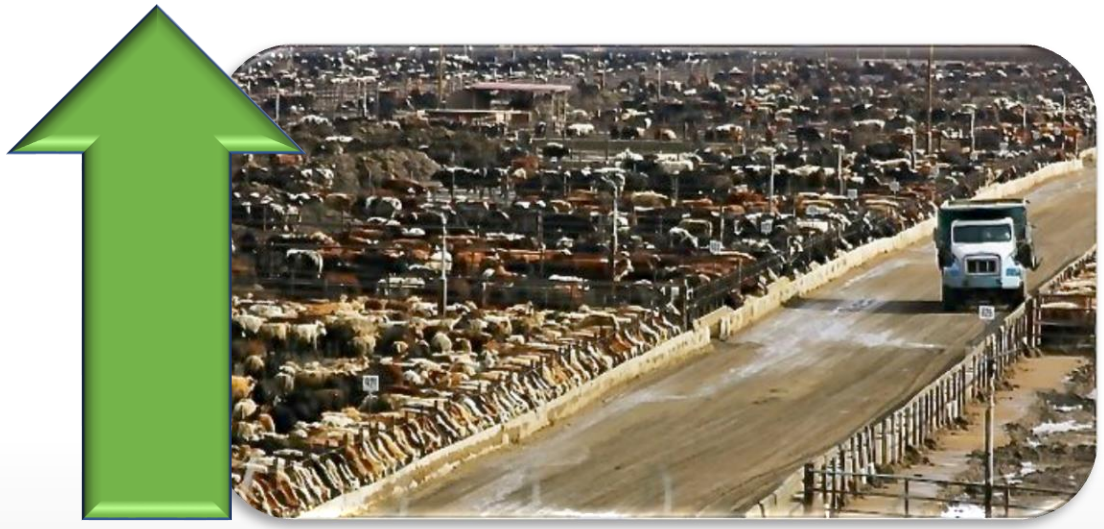
1. Stimuli (Abiotic, resources, social, predators, internal, pathogens)

5. Response (Physiology, Behaviour, Immune, Morphology and Cognition)

Colditz and Hine, 2016


Causal factors: Interpretations of external changes and internal states of the body that serve as inputs to the decision-making centre.
External factors
Surroundings
Food characteristics
Internal factors
Previous experience
Body signals

Previous experience



Initiate feeding

Efficiency of finding food

Rate of ingestion

Other internal factors

Age

More efficient as they get older

Breed

Genetic component and selection

Gender

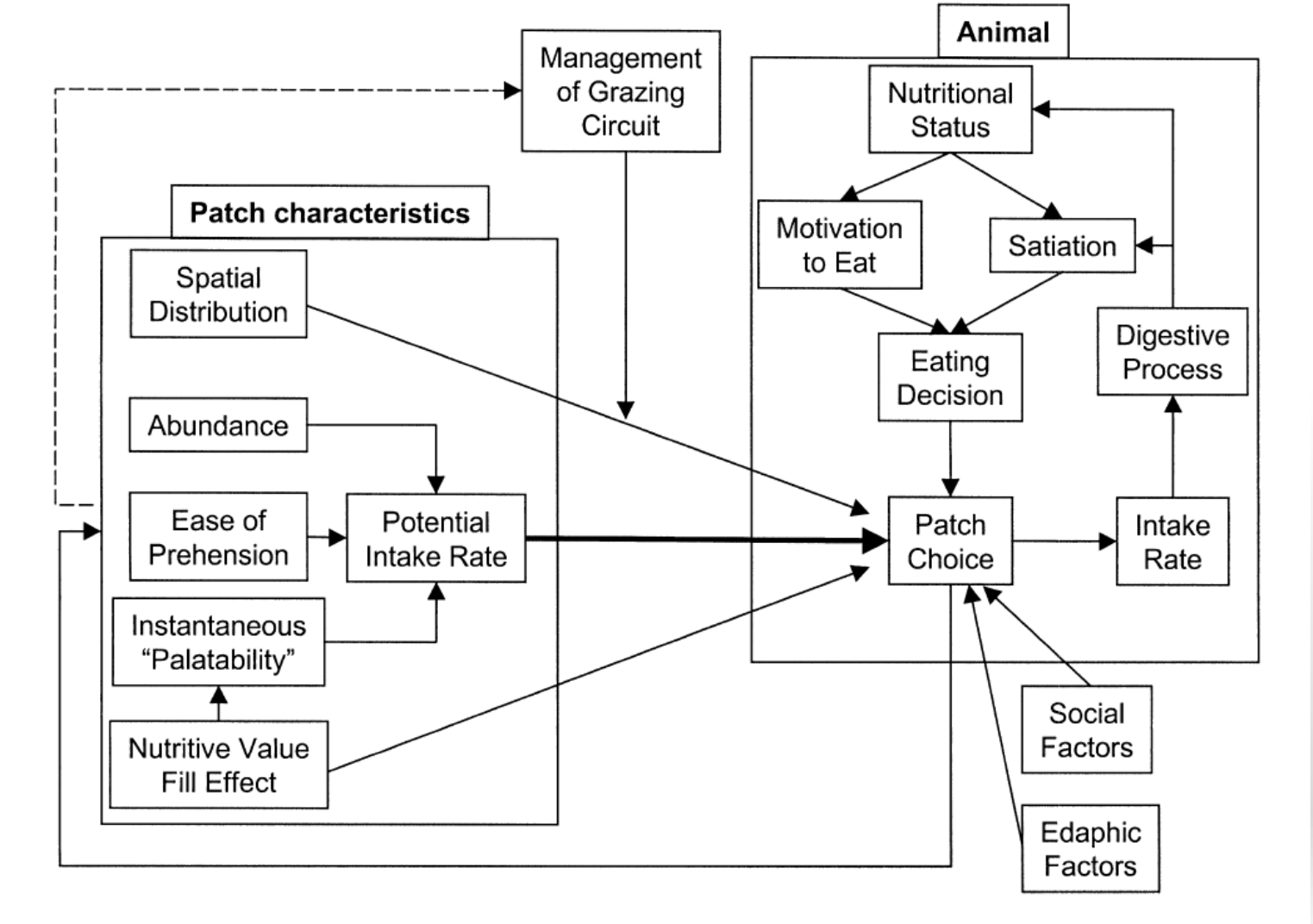
Social and hormonal differences

Feed-related factors affecting feeding behavior and ruminal fluid pH

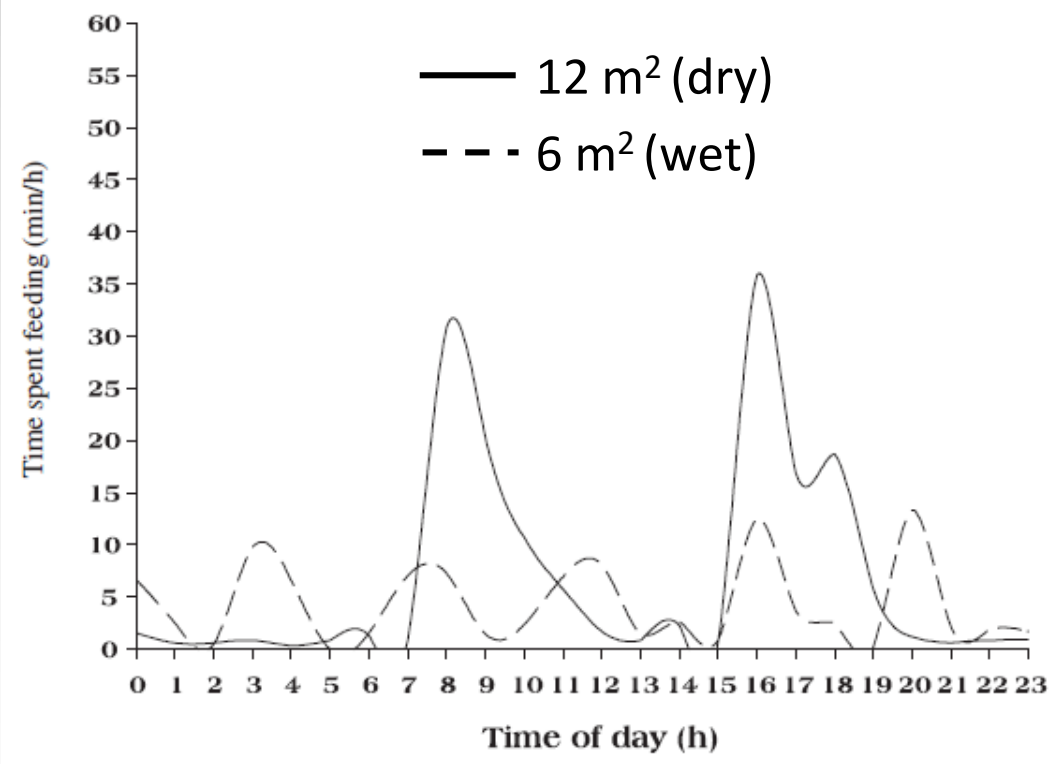
- Feed related factors affecting feeding behavior and rumen function:
  a) Amount and type of grain: NSC, effective fiber, rumen degradability
  b) Feed additives: monensin, sodium bicarbonate, flavours,…

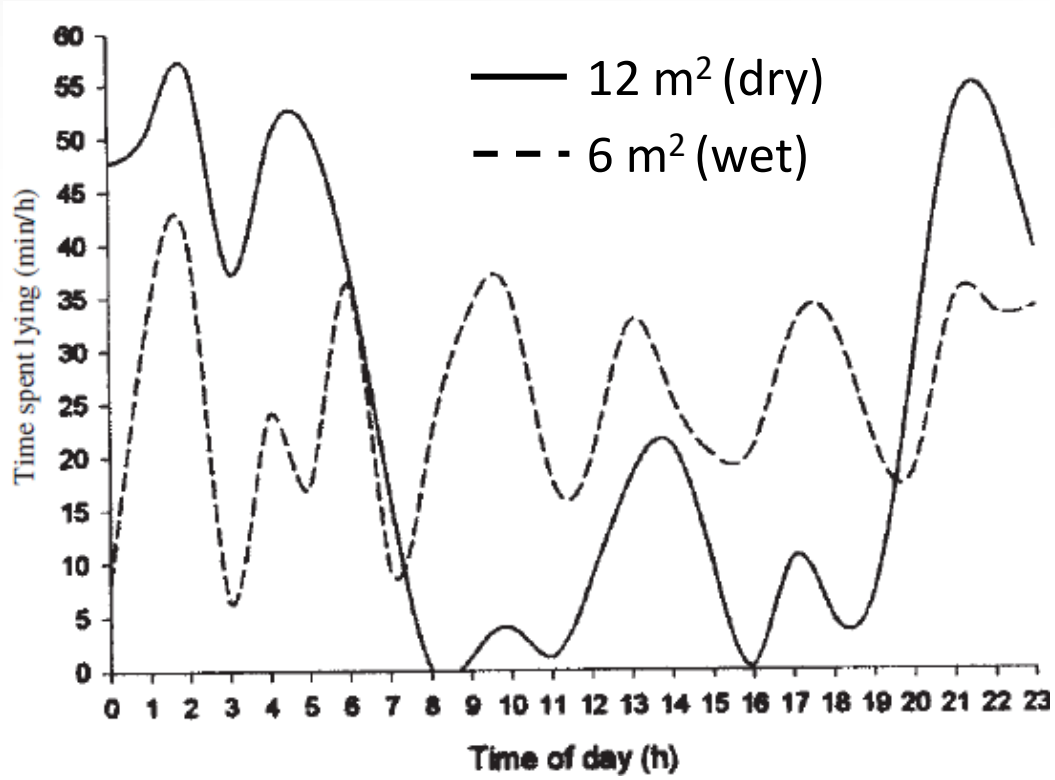
- Feeding management:
  a) Feeding frequency: More deliveries, more stable rumen.
  b) Feed bunk management: ad libitum vs restricted or clean bunk
  c) Consistency of feeding: Irregular schedules (delays, health status,…) may cause cattle to ingest large quantities of feed during a short time period once feed becomes available

How forage characteristics influence behaviour and intake in small ruminants (Baumont et al., 2010)



More external factors: Pen conditions





The difference in pattern of feeding and lying enabled the high-density cattle to cope relatively successfully with altered conditions.

Wilson et al., 2005

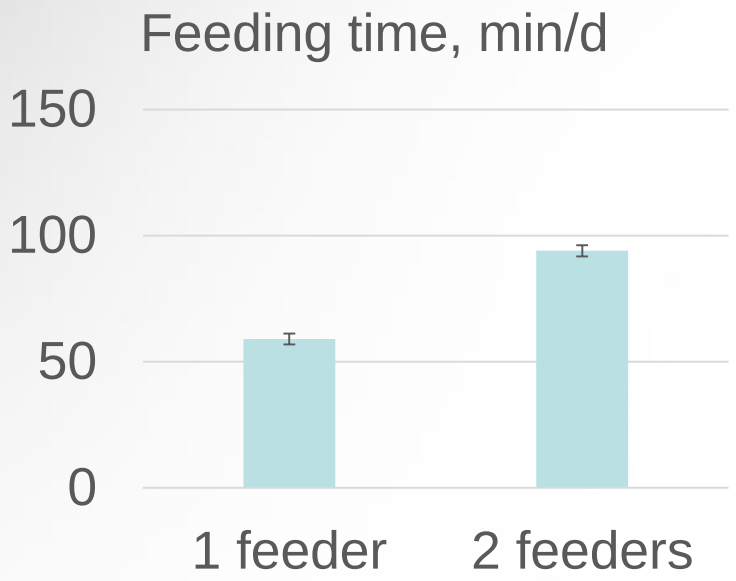
Competition

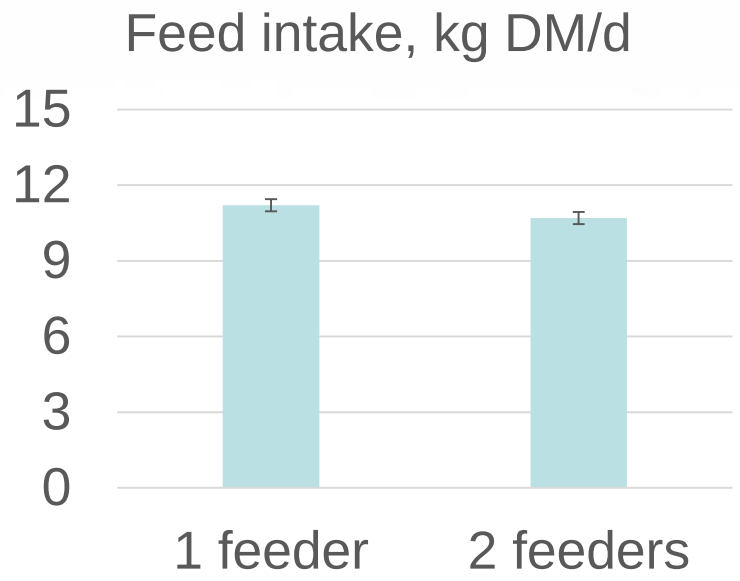
Animals graze at faster rates when they know that the herbage available is limited

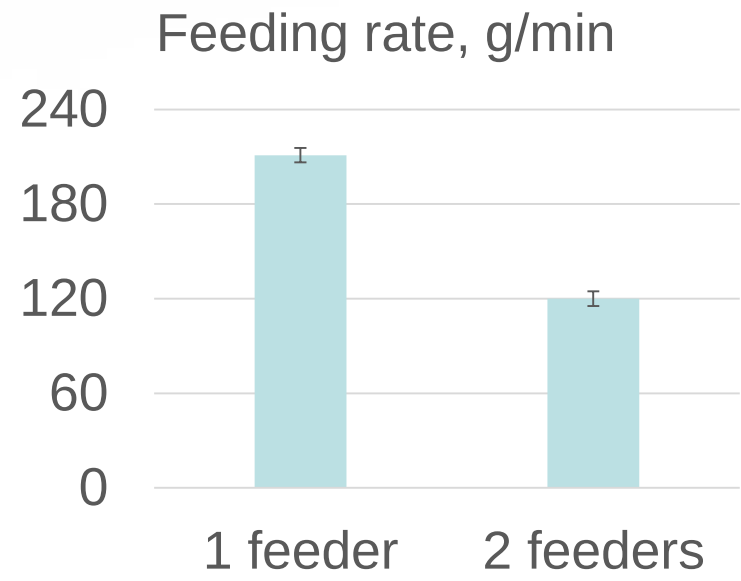
Picture: www.punjab-tourism.com

Effect of social pressure on feeding behaviour

Feeding groups of 15 growing heifers in 2 or 1 feeders per pen (n = 120):







Such an increase in eating rate would result in a reduction of 22 L/d in daily saliva production.

González et al., 2012

Other factors

- Temperature
- Photoperiod
- Pregnancy
- Disease

Picture: www.cutestpaw.com

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Monitoring location

GPS

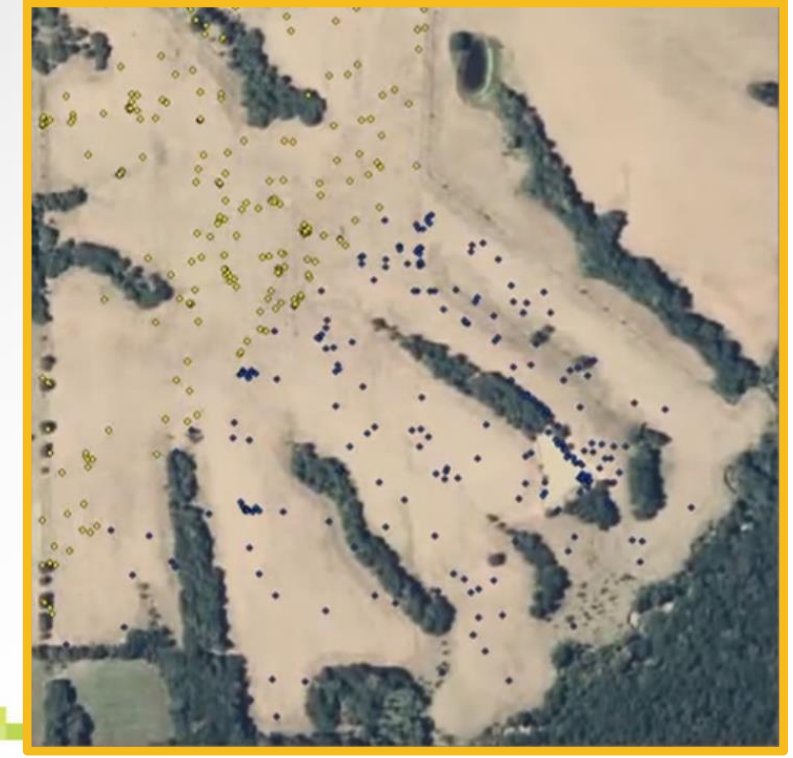
UWB sensors

Video

GPS trackers

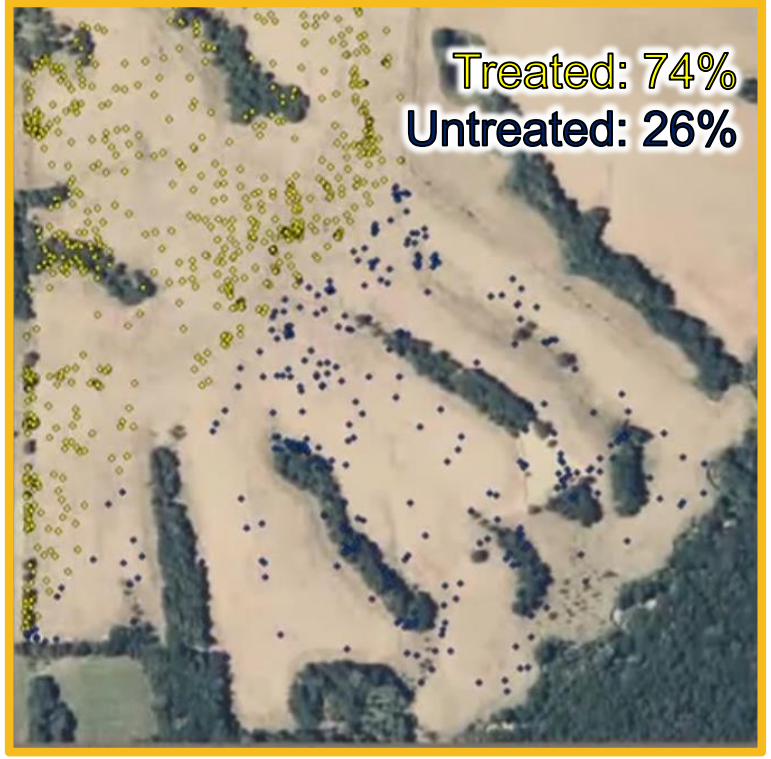
Using GPS the University of Missouri Extension weed scientists have learned that weed control improves pasture productivity and creates a grazing space preferred by most cows.

Before application



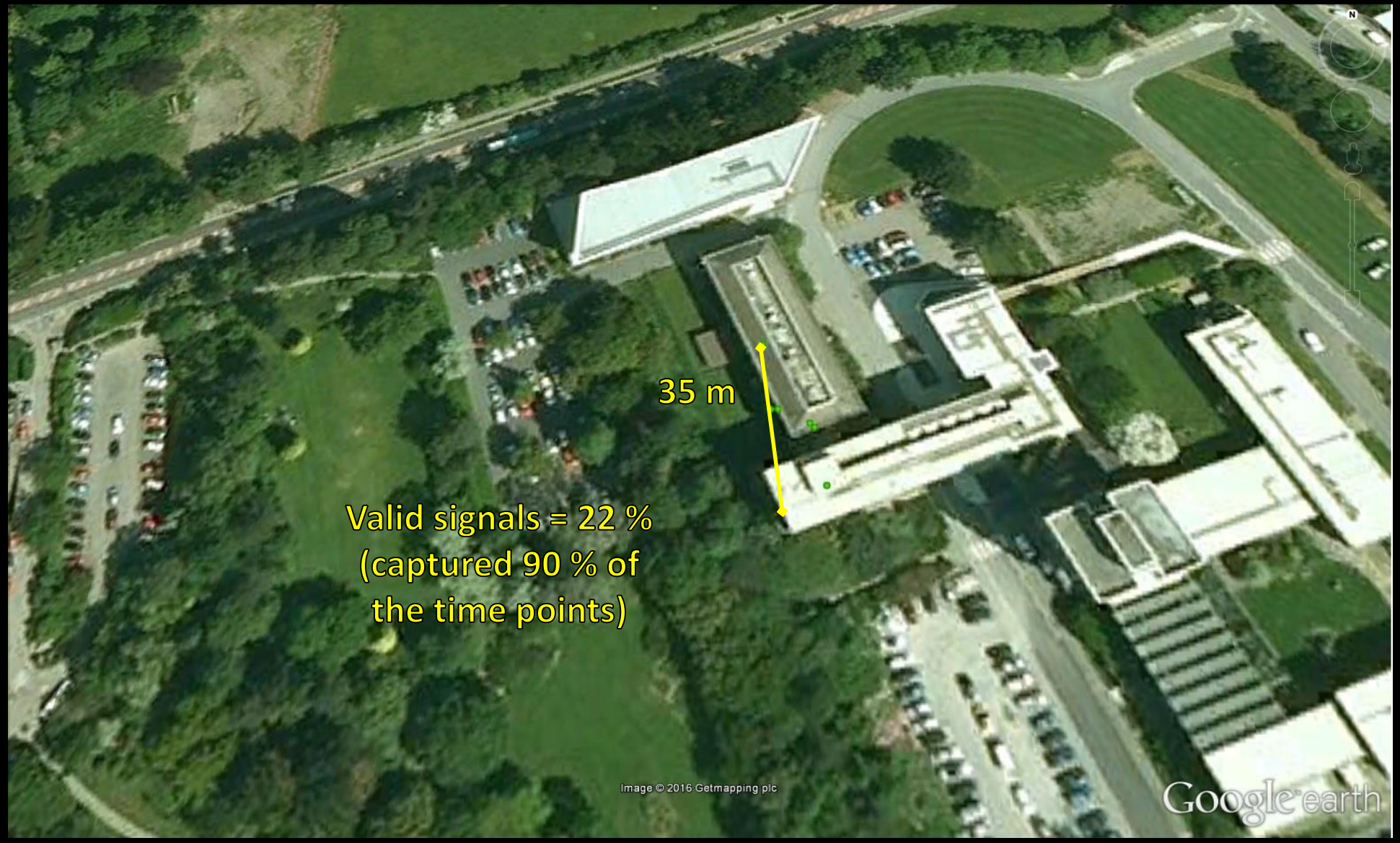
2 months after

4 months after

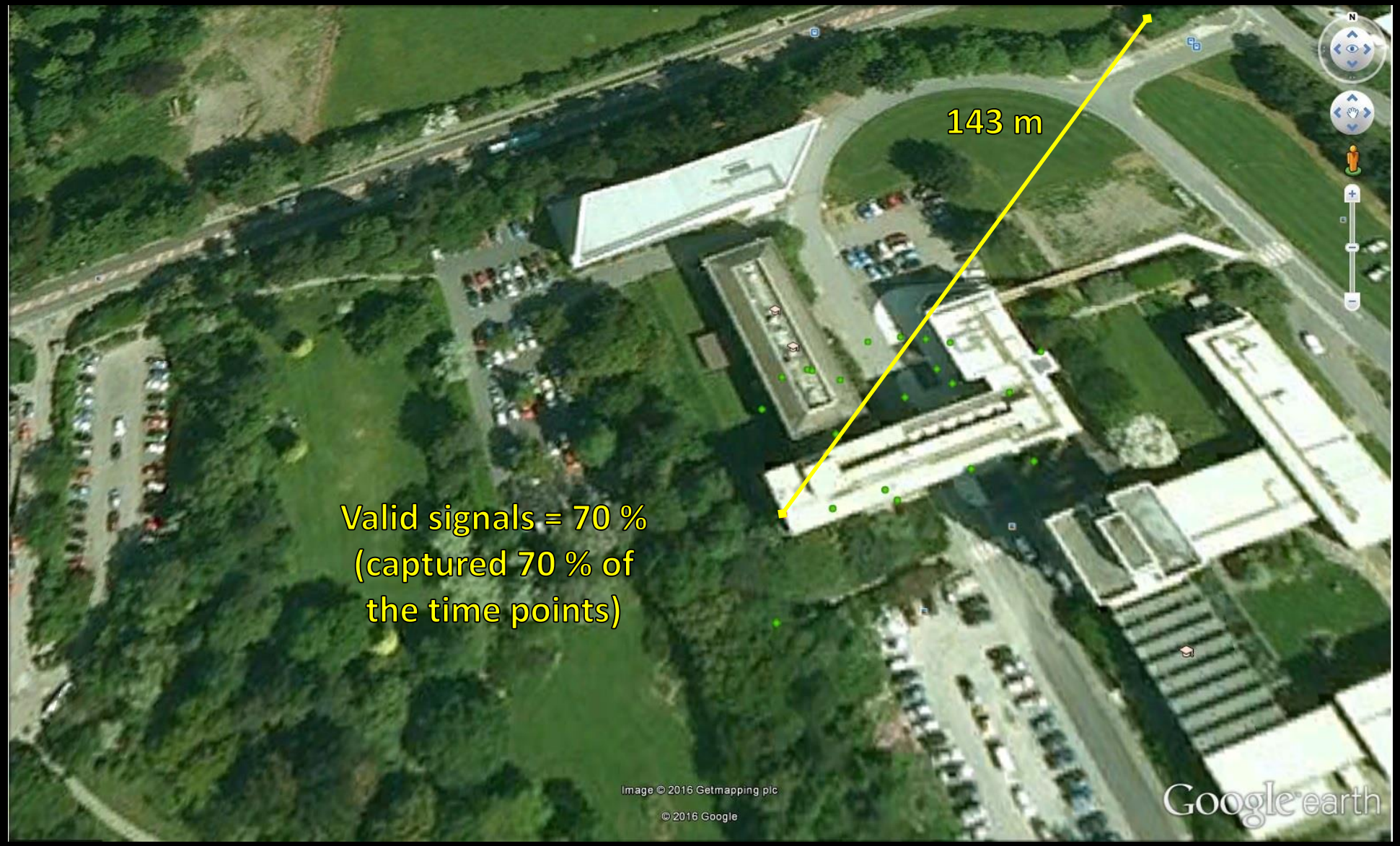


1 batch of 64 ms every 30 s for 5 min

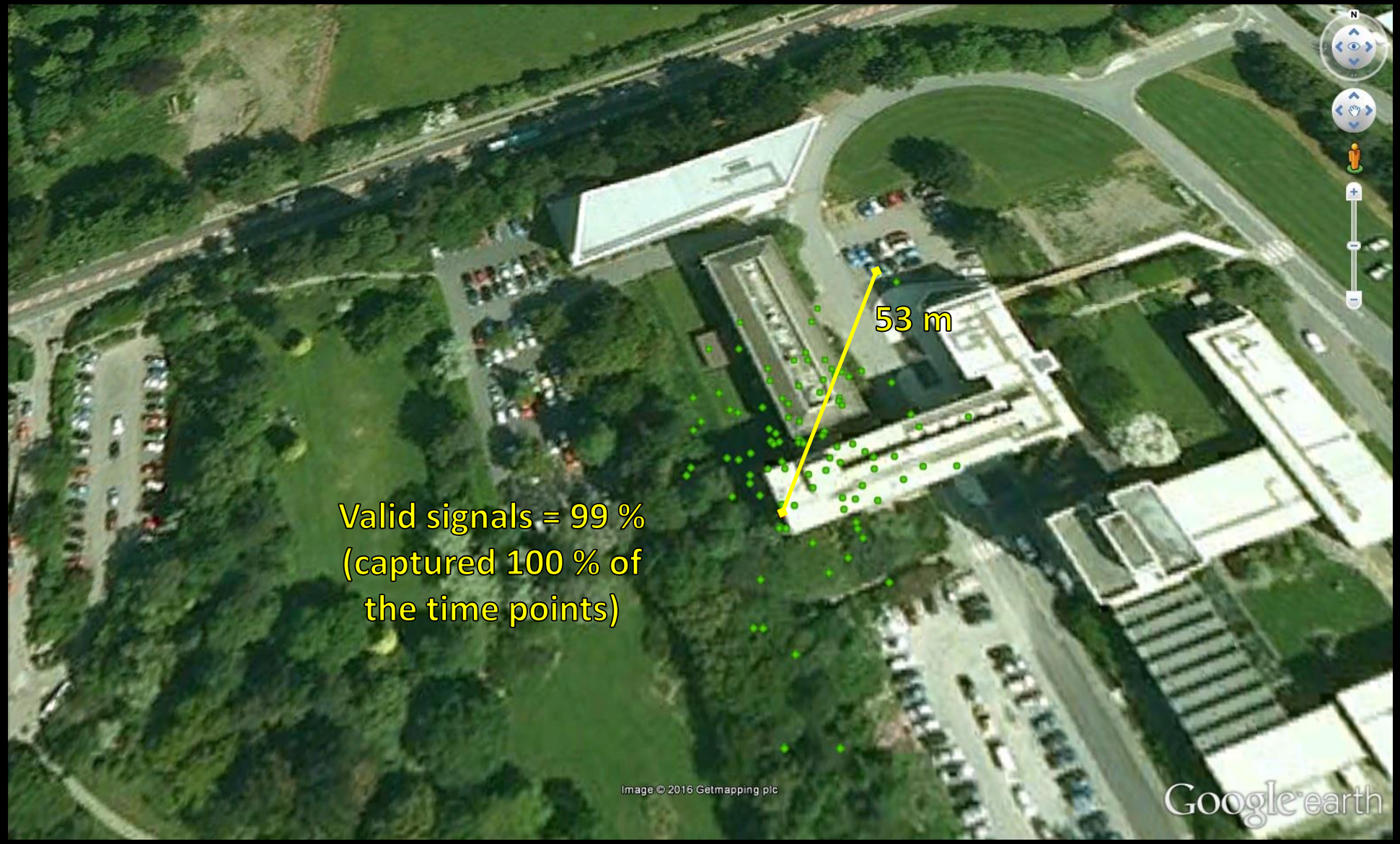
10 batches of 64 ms every 30 s for 5 min



1 batch of 512 ms every 30 s for 5 min



10 batches of 512 ms every 30 s for 5 min

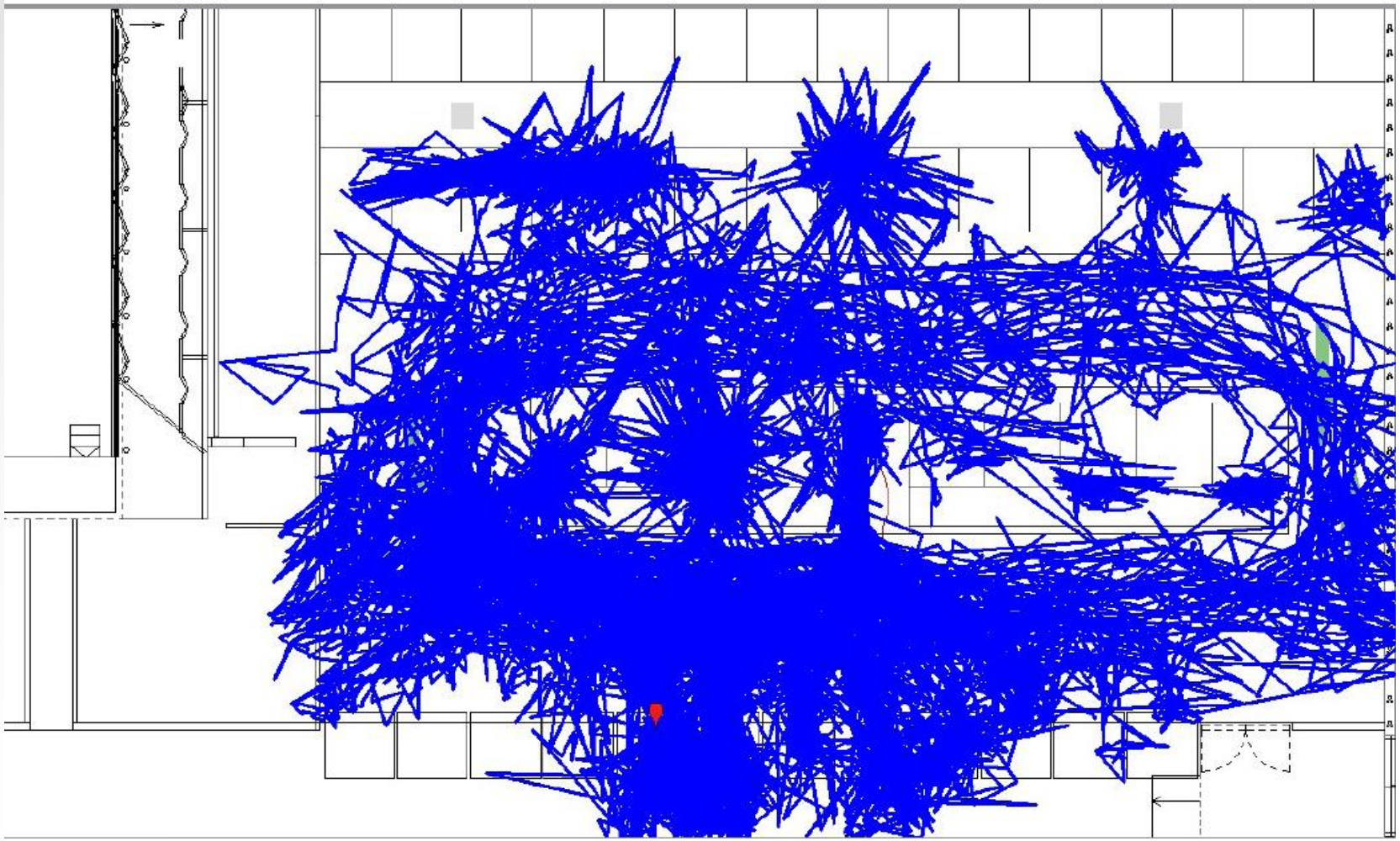


Tracking the location and movement of farm animals gives insight into the behaviour, health, and welfare of farm animals.

Ultra wide-band sensors

Tracking the location of farm animals gives insight into the behaviour, health, and welfare of farm animals.

UWB sensors on dairy cows



- Overall movement
- Individual speed
- Heat Map

NOLDUS TrackLab©

Used in a wide range of fields, mostly related to behavioural neurosciences, also in applied ethology, and animal welfare studies.

Methodology under development.

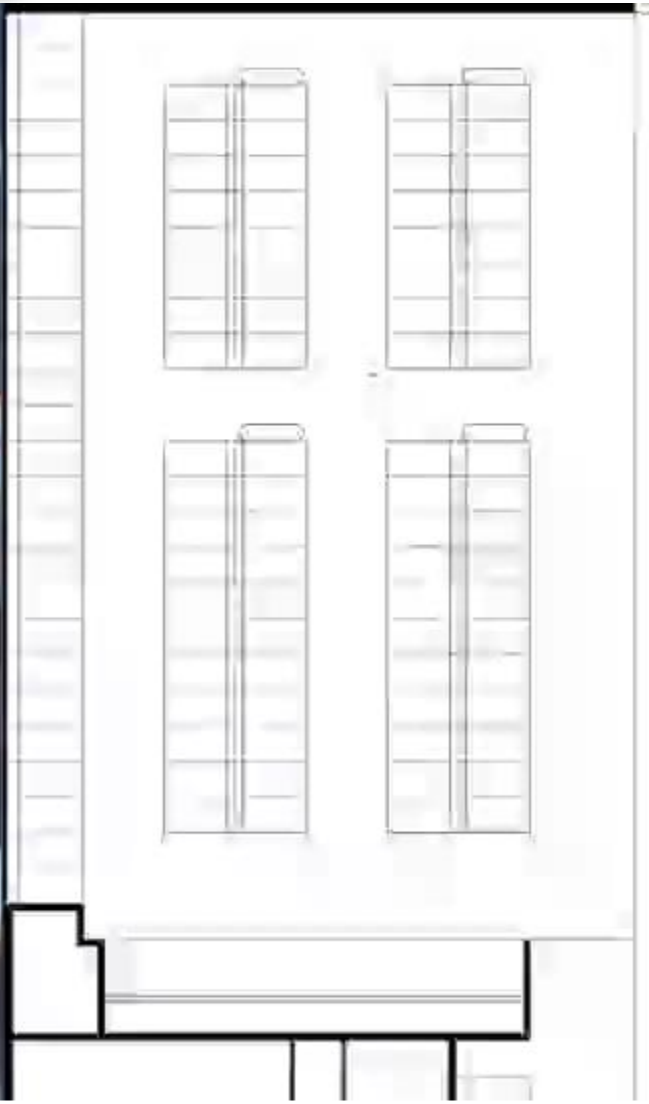
Click the Processing button

Sheep faces automatically recognised

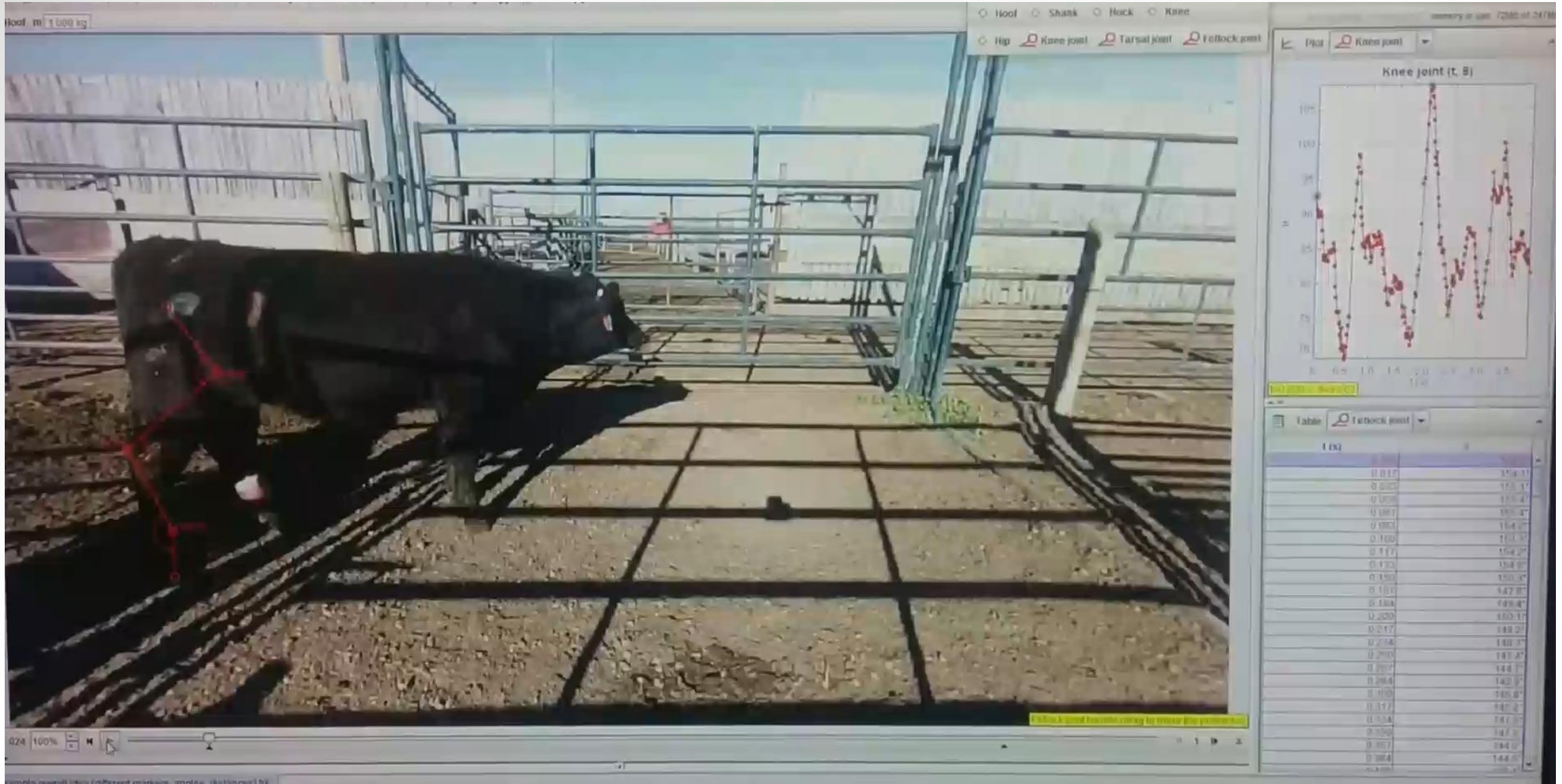
Markerless video tracking

Methodology under development.

Markerless video tracking



Markerless video tracking to assess cattle lameness



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Monitoring activity

Video Accelerometers Accoustics

Video recording: versatile but time consuming

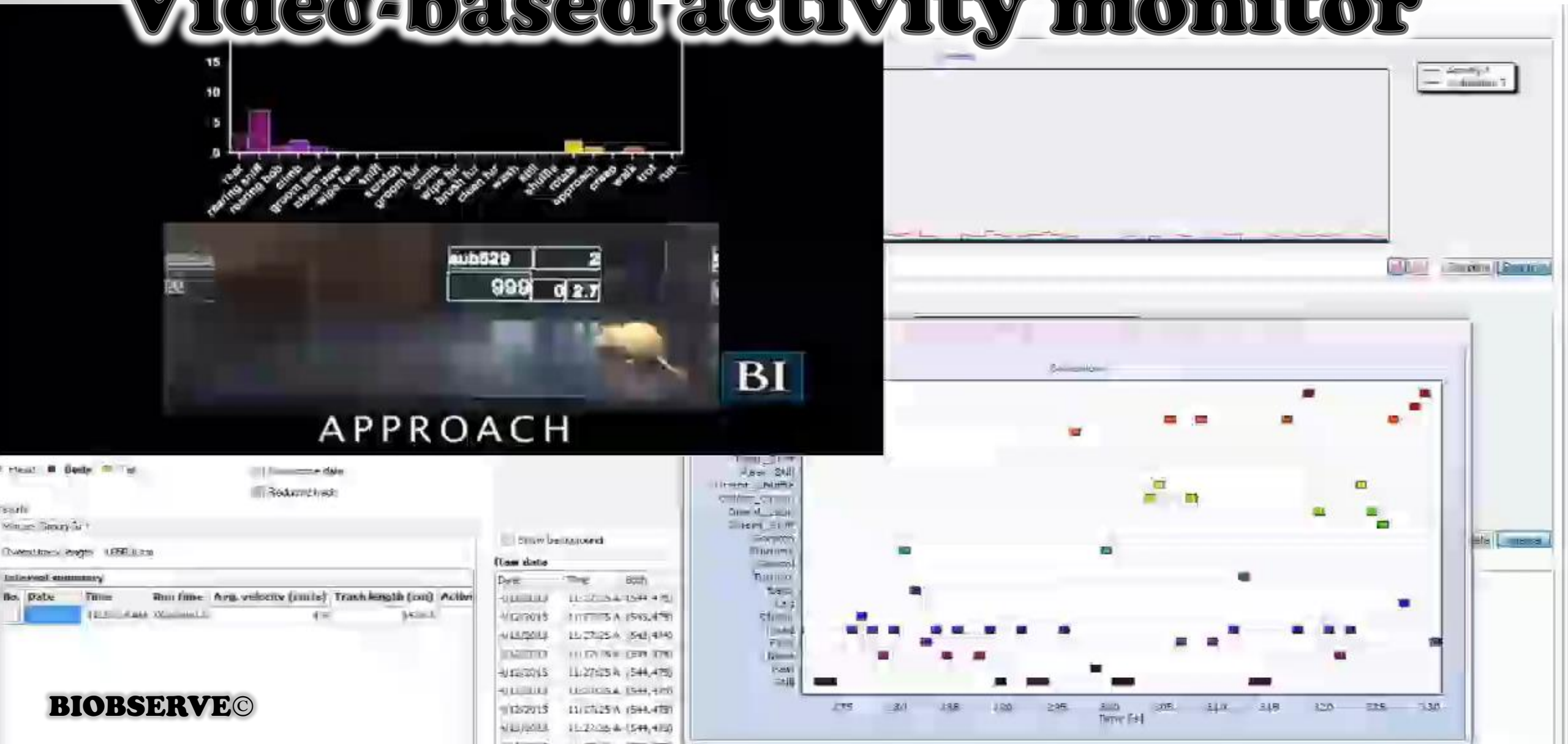

05/16/2019 12:00:06
PEN BEH2


05/16/2019 12:04:34
PEN BEH2

Video monitoring

Alternative to visual observation, where behaviours are determined by a pattern recognition algorithm based on visual data. Only in rodent models

Video-based activity monitor



Drones

- Fence checking
- Cow chasing
- Pasture scoping
- Crop/Range condition checking

- Research purposes

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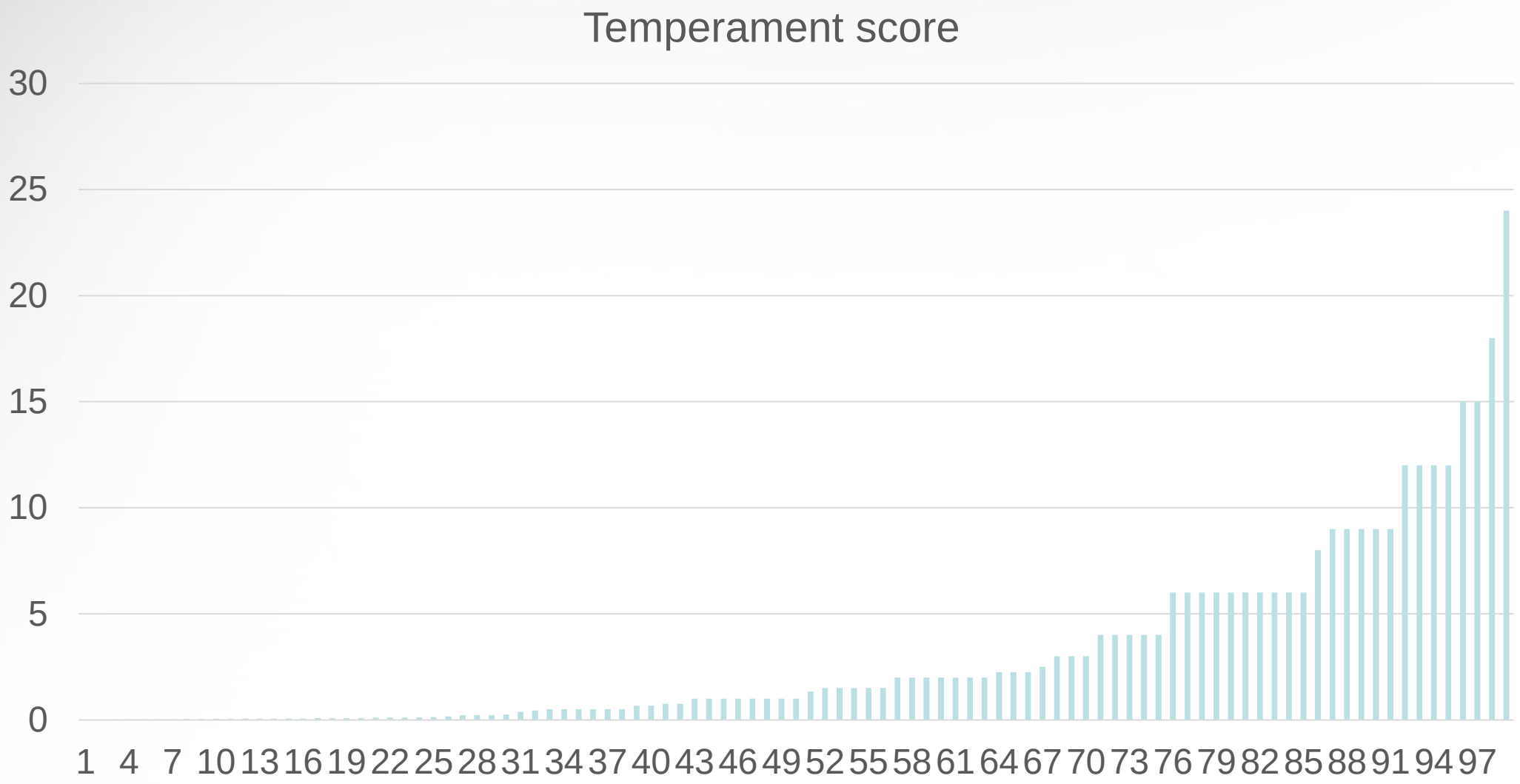
Mob grazing trial

1. Assess the performance and persistence of new legume and grass varieties under intensive grazing conditions across consecutive grazing seasons.
2. Characterize forage preference of the grazing animals.
3. Determine whether forage preference is related to forage performance and nutritive value.
4. Determine the effects of animal temperament on grazing behaviour and forage preference.

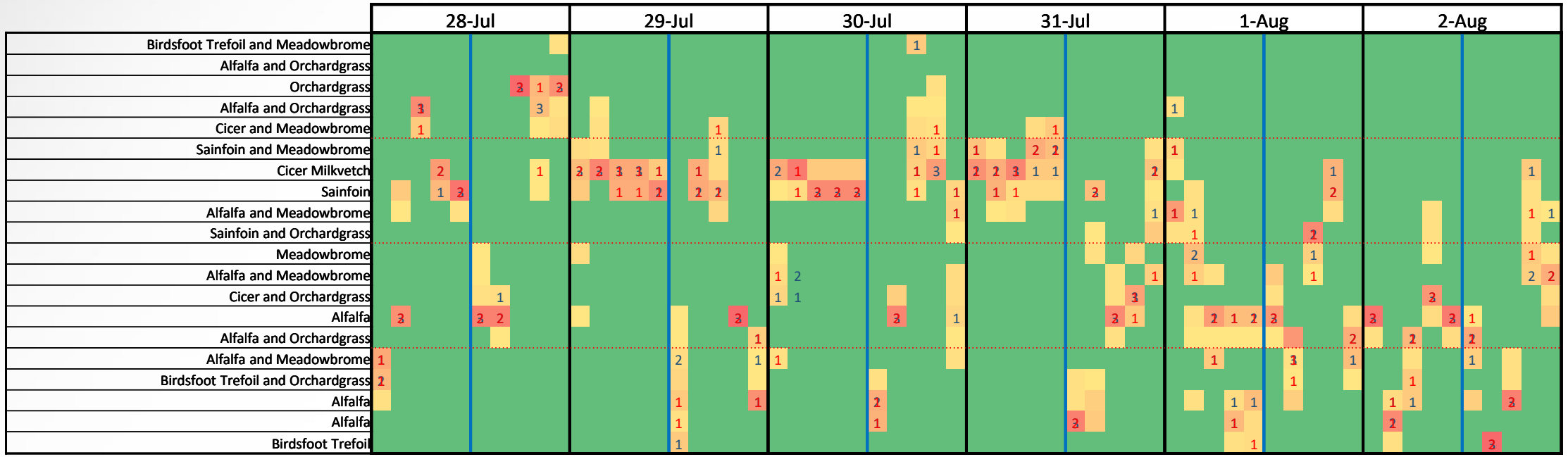
Corridor test

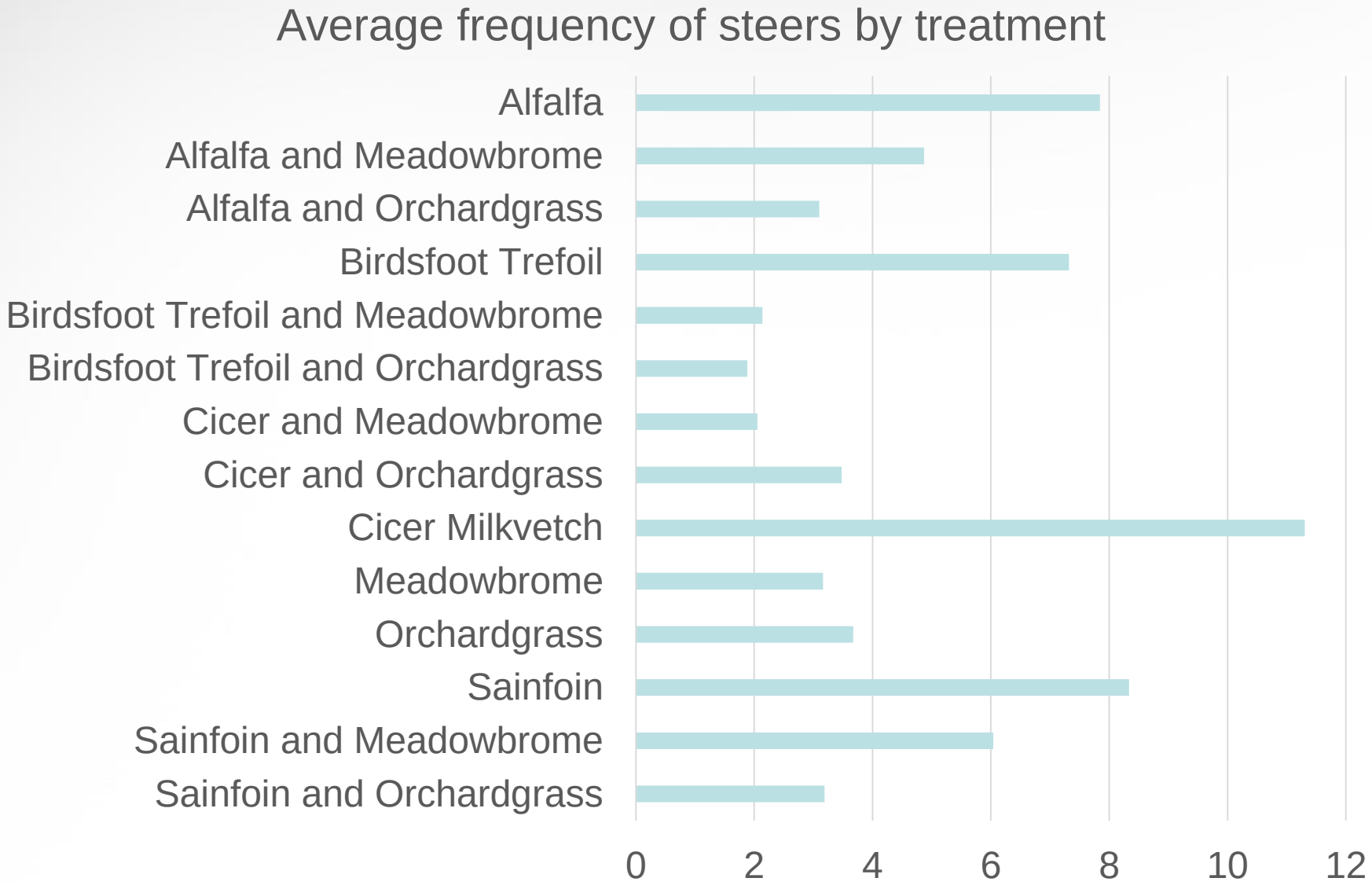
- Speed
- Lunges
- Head turns

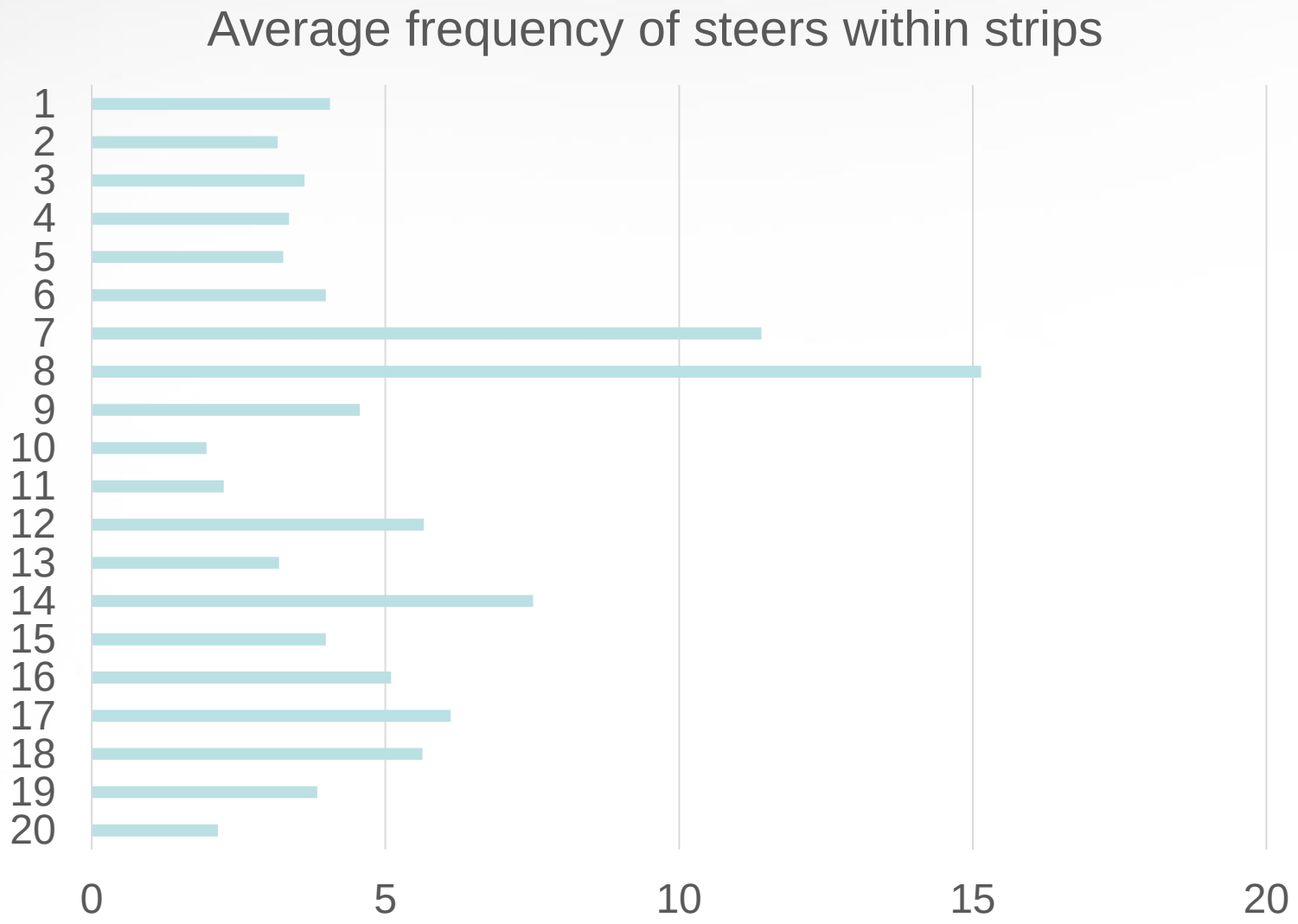

Nobel Object Test


Temperament score
30
25
20
15
10
5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97

Grazing preference




Average frequency of steers by treatment
Alfalfa
Alfalfa and Meadowbrome
Alfalfa and Orchardgrass
Birdsfoot Trefoil
Birdsfoot Trefoil and Meadowbrome
Birdsfoot Trefoil and Orchardgrass
Cicer and Meadowbrome
Cicer and Orchardgrass
Cicer Milkvetch
Meadowbrome
Orchardgrass
Sainfoin
Sainfoin and Meadowbrome
Sainfoin and Orchardgrass
0
2
4
6
8
10
12


Average frequency of steers within strips
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0
5
10
15
20

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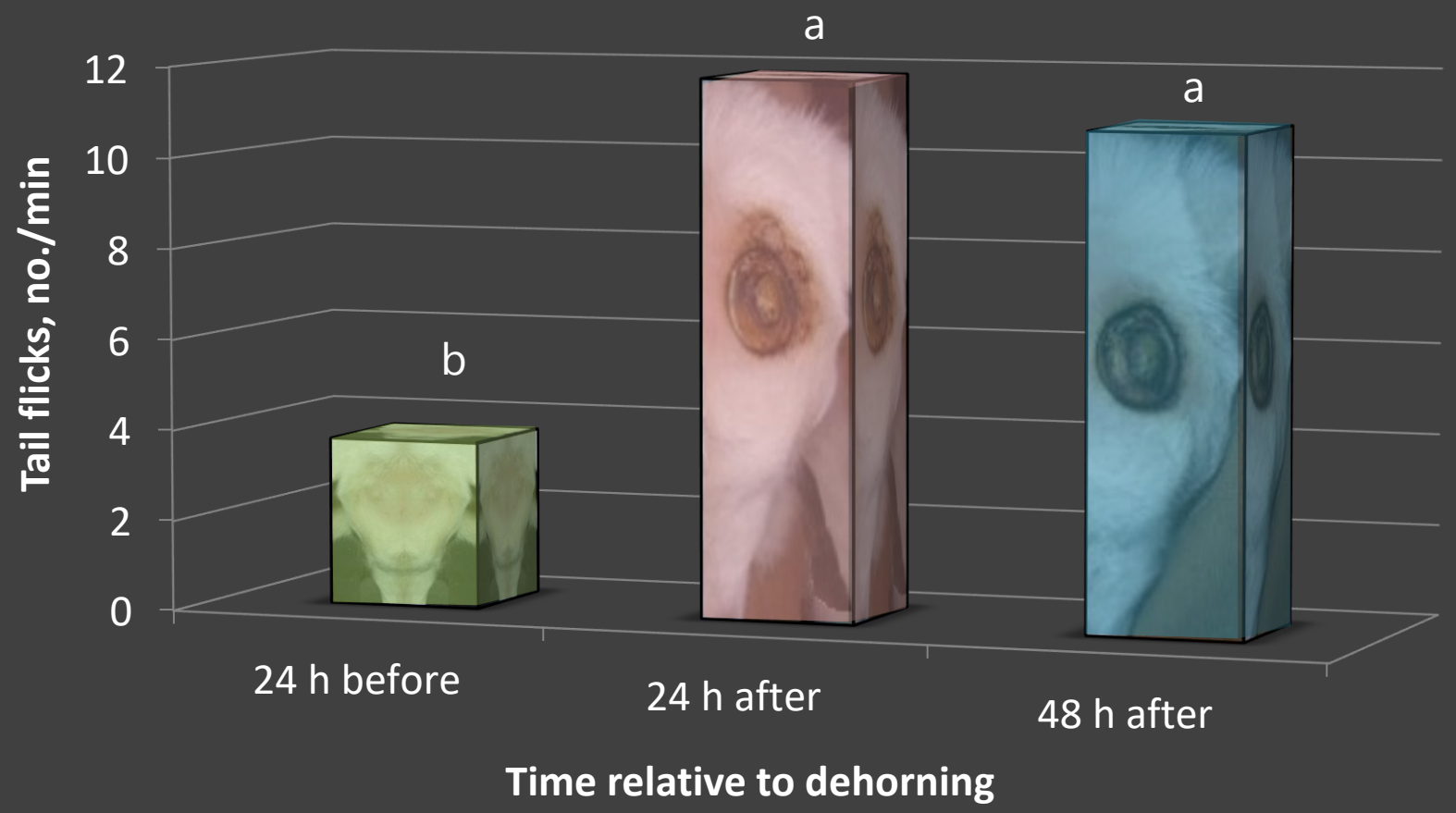
Use of accelerometers

A **tail flick** is a **muscle-powered** movement of the tail from its **straight down** resting position **to one side**. If the tail moves from side to side **crossing** its resting position, **another** tail movement is recorded.

Visual observation of tail-flicking behavior is **time consuming** and **subjective** in nature.

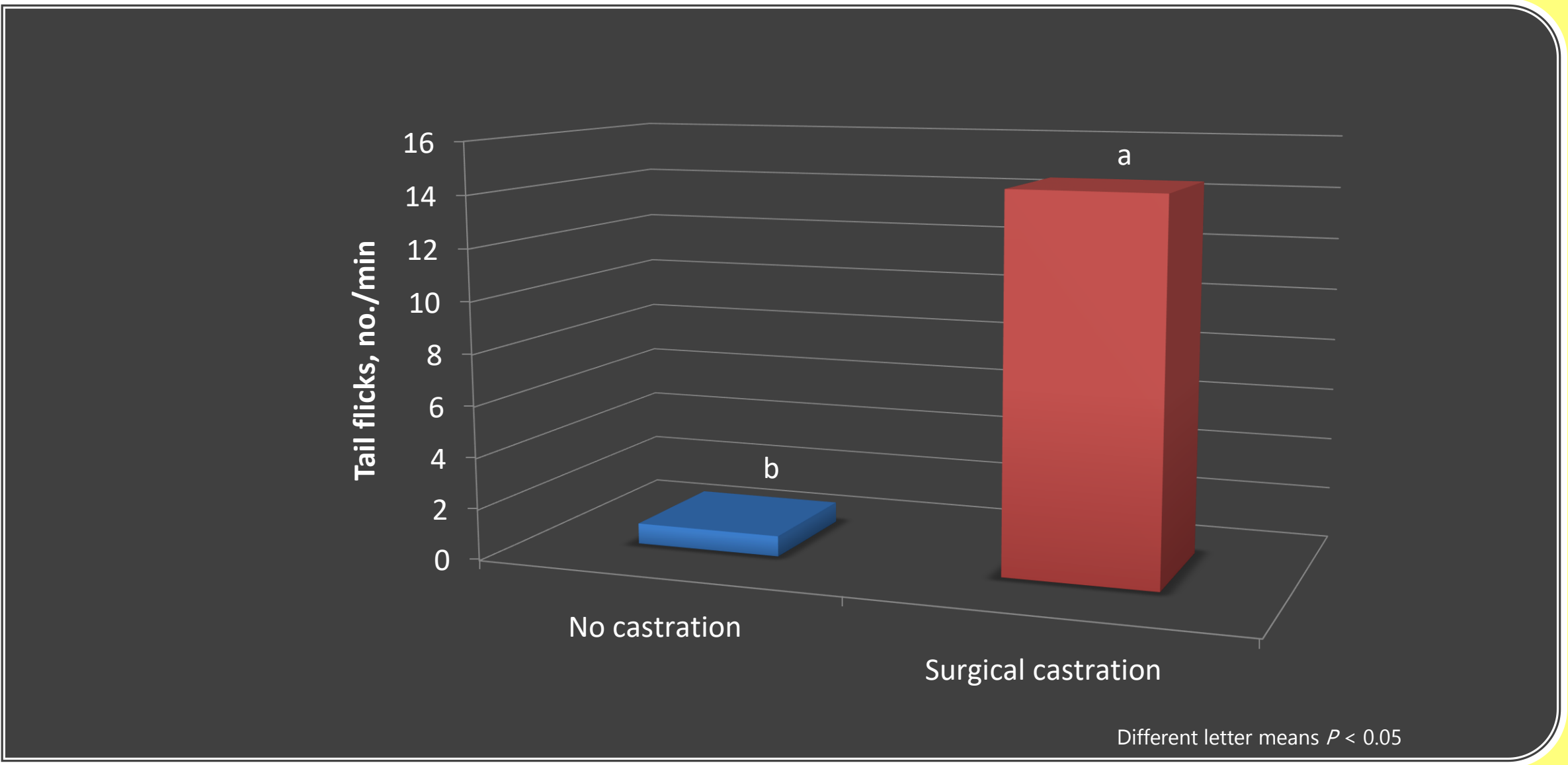
Dougherty et al., 1994. Appl. Anim. Behav. Sci. 40:113-127

Proxy for animal disscomfort



Heinrich et al., 2010. J. Dairy Sci. 93:2450-2457

Proxy for animal disscomfort



Fisher et al., 2001. Aust. Vet. J. 79:279-284

Hypothesis

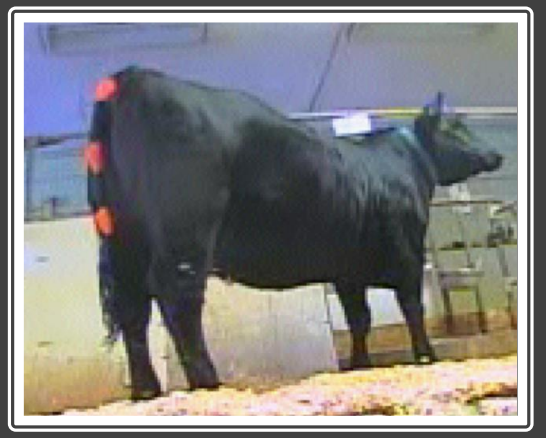
Possible **alternative** to visual observations, allowing researchers to measure tail motion with **minimal time** commitment and **less subjectivity**

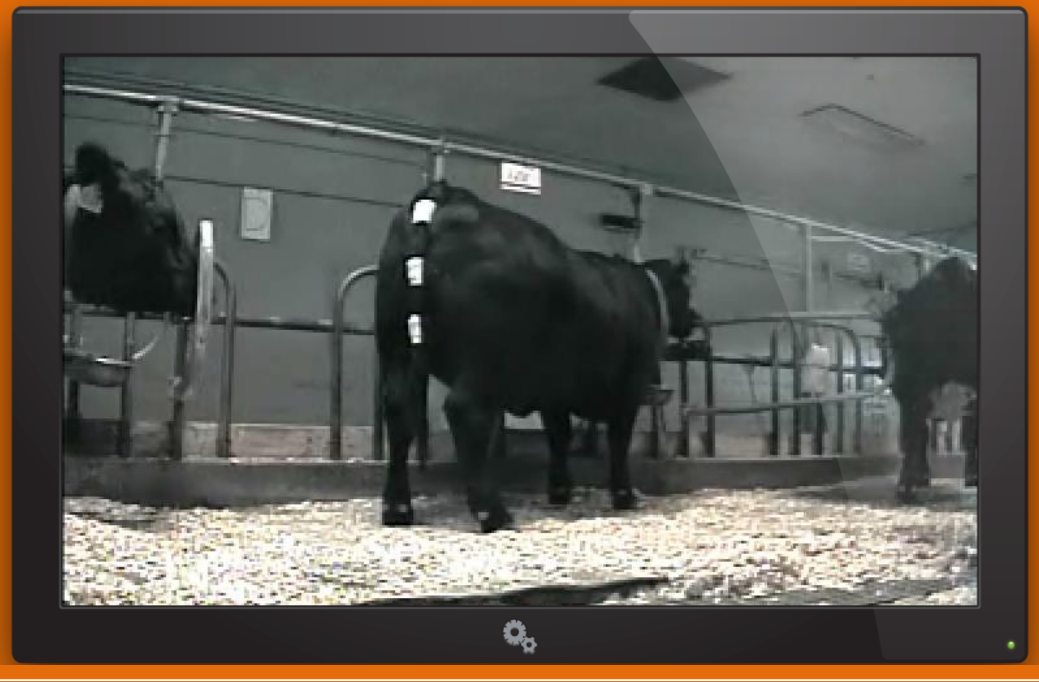
Materials and Methods

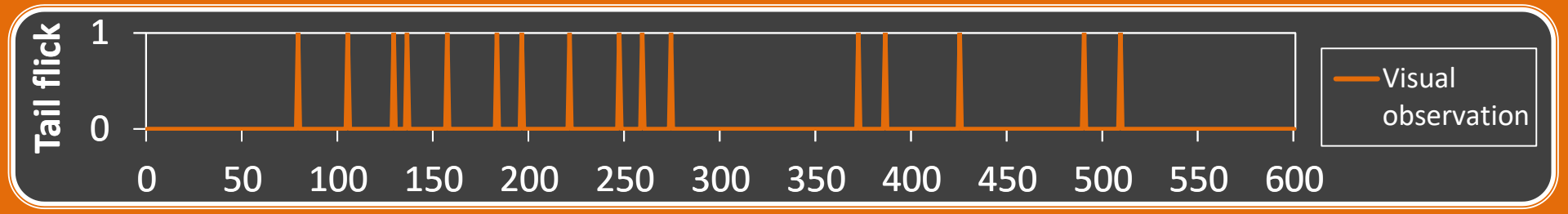
Accelerometers (HOBO Pendant G Data Loggers, Onset Computer Corporation, MA).

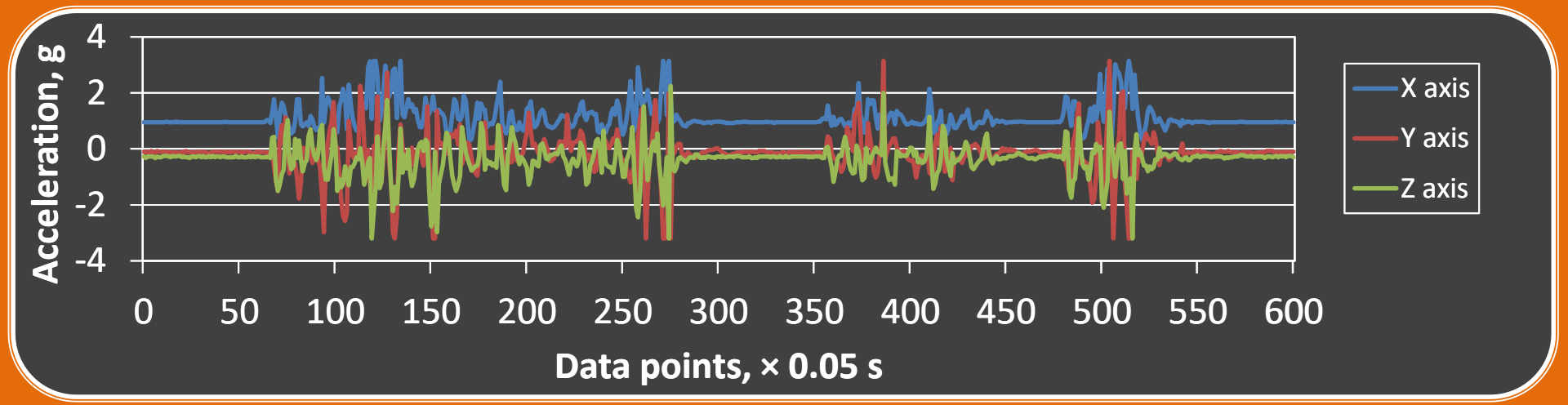
Affixed with vet wrap to the tail of 5 Angus cows housed in tie stalls.

3 different locations: 8 cm below the base, 26 cm below the base, and above the tail switch.

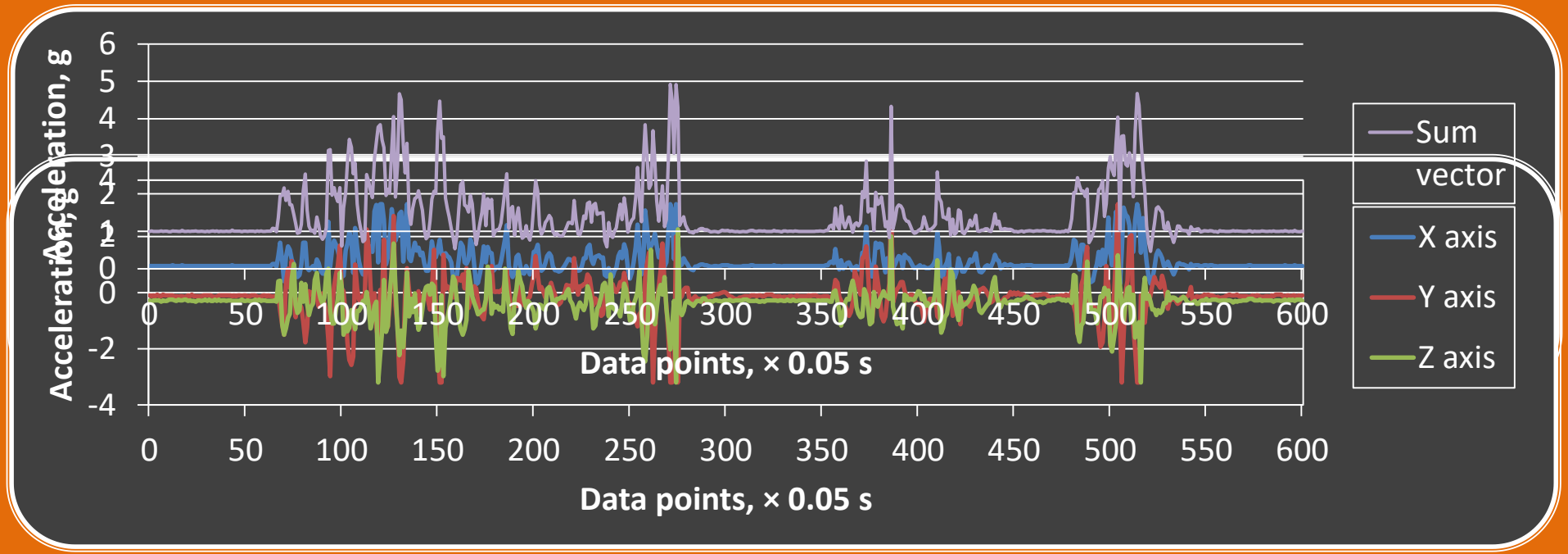





Tail flick
1
0
0
50
100
150
200
250
300
350
400
450
500
550
600
Visual observation

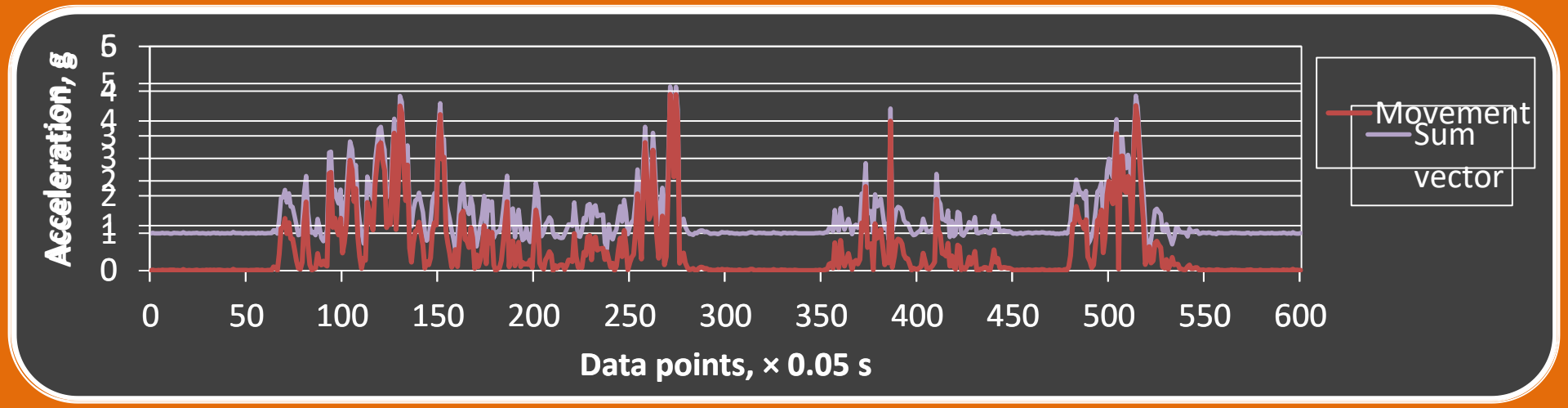

Acceleration, g
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
450
500
550
600
Data points, × 0.05 s
X axis
Y axis
Z axis

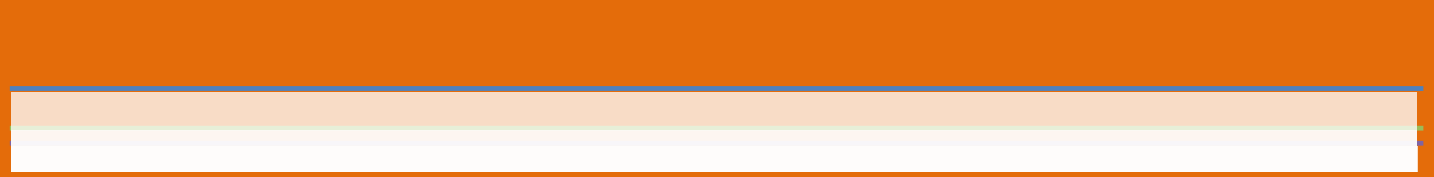
Sum vector = $\sqrt{(X^2 + Y^2 + Z^2)}$

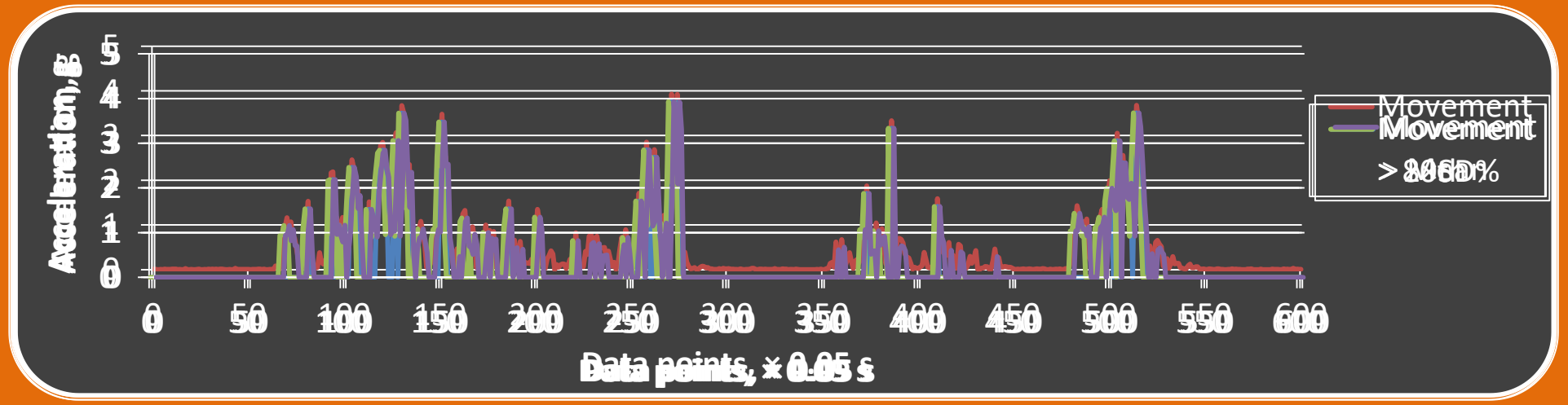


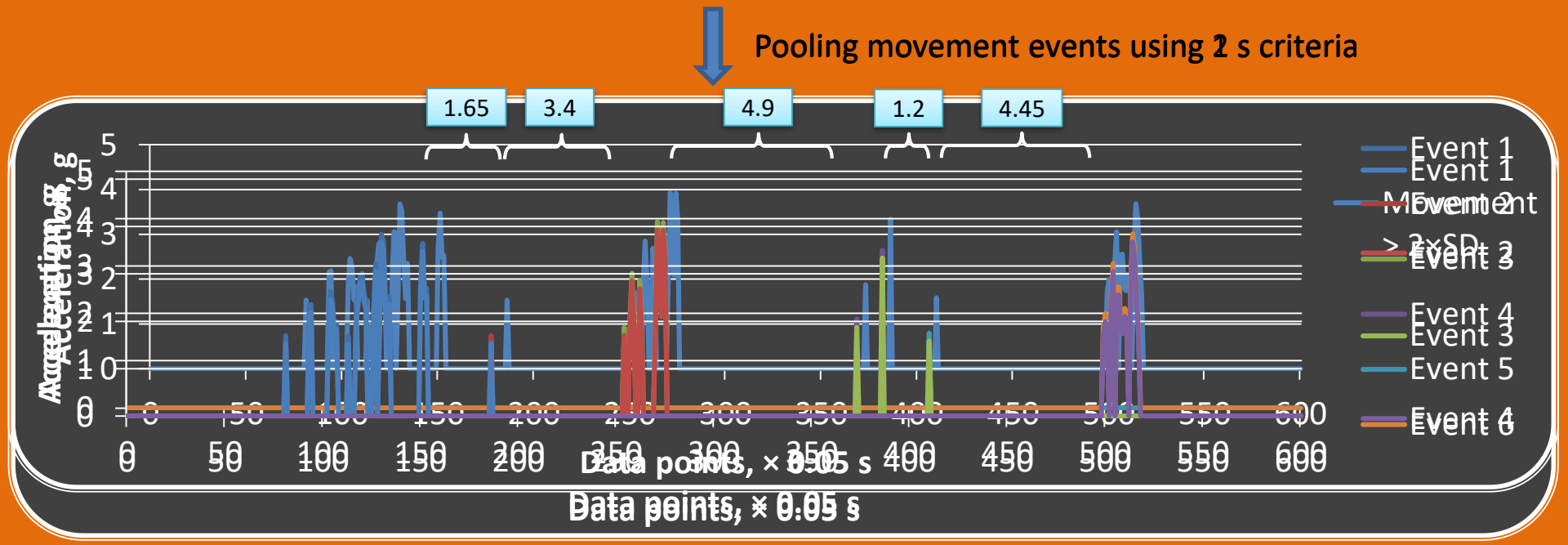
Mode

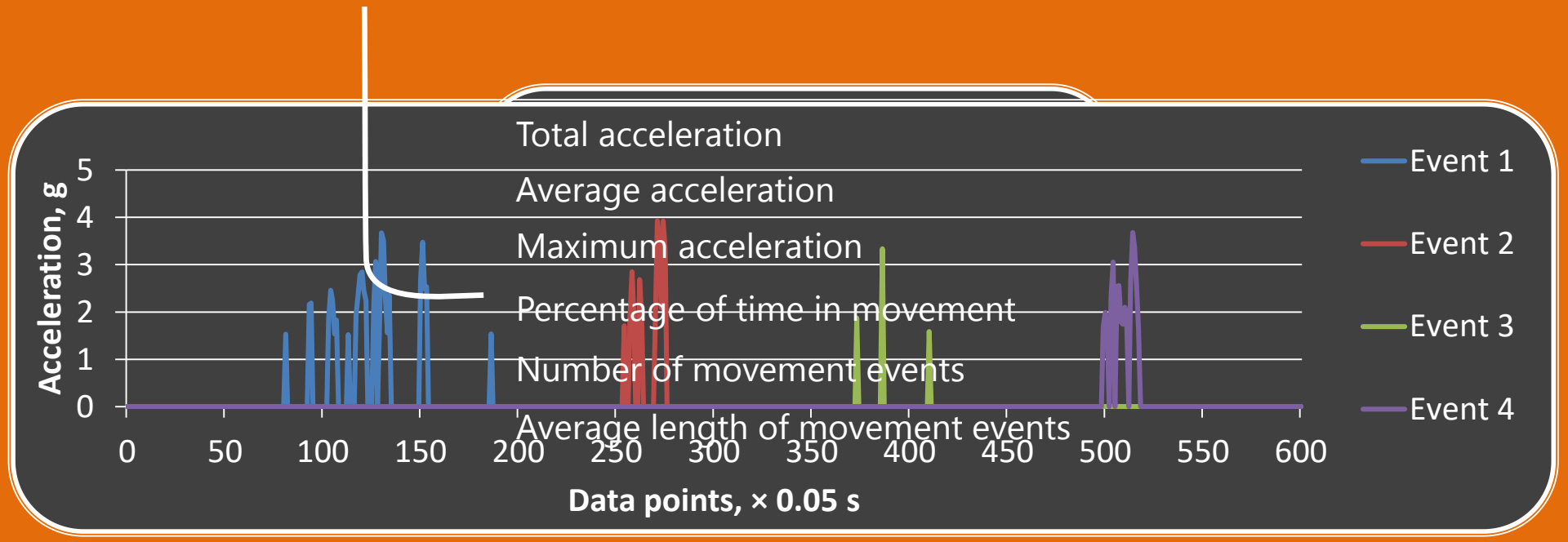
Zero the baseline acceleration when the tail is in resting position



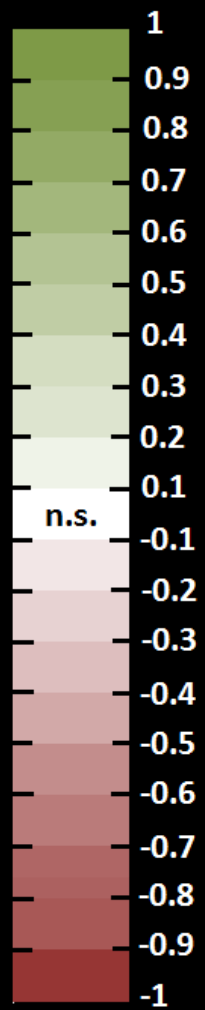

Mean
80th %
2 × SD


Movement
Movement
0
1
2
3
4
5
0
50
100
150
200
250
300
350
400
450
500
550
600


Pooling movement events using 2 s criteria
1.65
3.4
4.9
1.2
4.45
Acceleration, g
Data points, × 0.05 s
Movement > 3×SD
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6


Total acceleration
Average acceleration
Maximum acceleration
Percentage of time in movement
Number of movement events
Average length of movement events
Acceleration, g
0
1
2
3
4
5
0
50
100
150
200
250
300
350
400
450
500
550
600
Data points, × 0.05 s
Event 1
Event 2
Event 3
Event 4

Movement criteria	Intentionality threshold	Accelerometer location	Animal position	N	Correlation between visual observation and accelerometers					
					Total acceleration	Maximum Acceleration	Number of movements	Average Acceleration	Percentage of time in movement	Average length of movement
1 sec	2STDEV	Top	Standing	30	0.92	0.47	0.44	0.81	0.73	0.24
1 sec	2STDEV	Top	Lying	12	0.50	0.35	0.67	0.36	0.13	-0.40
1 sec	2STDEV	Top	Both	7	0.82	-0.19	0.78	0.75	0.58	-0.75
1 sec	2STDEV	Middle	Standing	29	0.87	0.46	0.57	0.85	0.82	0.43
1 sec	2STDEV	Middle	Lying	12	0.79	0.40	0.94	0.72	0.83	-0.71
1 sec	2STDEV	Middle	Both	7	0.89	0.62	0.86	0.73	0.84	-0.24
1 sec	2STDEV	Bottom	Standing	30	0.91	0.47	0.77	0.79	0.92	0.51
1 sec	2STDEV	Bottom	Lying	12	0.74	0.22	0.97	0.69	0.80	-0.25
1 sec	2STDEV	Bottom	Both	7	0.86	0.72	0.85	0.67	0.94	0.29
1 sec	80PERCENTILE	Top	Standing	30	0.92	0.47	0.51	0.94	-0.45	-0.43
1 sec	80PERCENTILE	Top	Lying	12	0.51	0.35	0.60	0.48	-0.40	-0.70
1 sec	80PERCENTILE	Top	Both	7	0.78	-0.19	0.84	0.79	-0.80	-0.84
1 sec	80PERCENTILE	Middle	Standing	29	0.92	0.46	0.41	0.92	0.20	-0.30
1 sec	80PERCENTILE	Middle	Lying	12	0.84	0.40	0.50	0.82	0.33	-0.28
1 sec	80PERCENTILE	Middle	Both	7	0.92	0.62	0.69	0.92	0.70	-0.61
1 sec	80PERCENTILE	Bottom	Standing	30	0.94	0.47	0.32	0.93	-0.13	-0.35
1 sec	80PERCENTILE	Bottom	Lying	12	0.81	0.22	0.69	0.79	-0.61	-0.80
1 sec	80PERCENTILE	Bottom	Both	7	0.89	0.72	0.89	0.90	-0.23	-0.83
1 sec	MEAN	Top	Standing	30	0.93	0.47	0.60	0.89	-0.16	-0.32
1 sec	MEAN	Top	Lying	12	0.37	0.35	0.79	0.52	-0.65	-0.78
1 sec	MEAN	Top	Both	7	0.24	-0.19	0.58	0.84	-0.29	-0.40
1 sec	MEAN	Middle	Standing	29	0.91	0.46	0.56	0.89	0.23	-0.25
1 sec	MEAN	Middle	Lying	12	0.81	0.40	0.25	0.77	-0.81	-0.76
1 sec	MEAN	Middle	Both	7	0.89	0.62	0.62	0.86	0.01	-0.16
1 sec	MEAN	Bottom	Standing	30	0.93	0.47	0.58	0.84	0.36	-0.19
1 sec	MEAN	Bottom	Lying	12	0.79	0.22	0.77	0.73	-0.79	-0.80
1 sec	MEAN	Bottom	Both	7	0.95	0.72	0.82	0.71	0.14	-0.35
2 sec	2STDEV	Top	Standing	30	0.93	0.47	0.38	0.81	0.76	0.28
2 sec	2STDEV	Top	Lying	12	0.52	0.35	0.73	0.36	0.14	-0.45
2 sec	2STDEV	Top	Both	7	0.83	-0.19	0.79	0.74	0.61	-0.72
2 sec	2STDEV	Middle	Standing	29	0.88	0.46	0.58	0.85	0.84	0.44
2 sec	2STDEV	Middle	Lying	12	0.81	0.40	0.90	0.73	0.86	-0.69
2 sec	2STDEV	Middle	Both	7	0.88	0.62	0.84	0.73	0.84	-0.28
2 sec	2STDEV	Bottom	Standing	30	0.91	0.47	0.73	0.78	0.93	0.59
2 sec	2STDEV	Bottom	Lying	12	0.76	0.22	0.90	0.71	0.83	-0.13
2 sec	2STDEV	Bottom	Both	7	0.86	0.72	0.83	0.68	0.94	0.22
2 sec	80PERCENTILE	Top	Standing	30	0.92	0.47	0.77	0.94	-0.49	-0.66
2 sec	80PERCENTILE	Top	Lying	12	0.51	0.35	0.79	0.49	-0.43	-0.78
2 sec	80PERCENTILE	Top	Both	7	0.78	-0.19	0.70	0.79	-0.77	-0.71
2 sec	80PERCENTILE	Middle	Standing	29	0.92	0.46	0.68	0.92	-0.05	-0.56
2 sec	80PERCENTILE	Middle	Lying	12	0.84	0.40	0.71	0.82	0.30	-0.56
2 sec	80PERCENTILE	Middle	Both	7	0.93	0.62	0.58	0.92	0.67	-0.52
2 sec	80PERCENTILE	Bottom	Standing	30	0.94	0.47	0.67	0.93	-0.23	-0.30
2 sec	80PERCENTILE	Bottom	Lying	12	0.81	0.22	0.74	0.79	-0.60	-0.84
2 sec	80PERCENTILE	Bottom	Both	7	0.89	0.72	0.86	0.90	-0.33	-0.81
2 sec	MEAN	Top	Standing	30	0.93	0.47	0.77	0.89	-0.18	-0.42
2 sec	MEAN	Top	Lying	12	0.37	0.35	0.68	0.52	-0.66	-0.63
2 sec	MEAN	Top	Both	7	0.24	-0.19	0.66	0.84	-0.29	-0.43
2 sec	MEAN	Middle	Standing	29	0.91	0.46	0.69	0.89	0.21	-0.27
2 sec	MEAN	Middle	Lying	12	0.81	0.40	0.73	0.77	-0.81	-0.85
2 sec	MEAN	Middle	Both	7	0.89	0.62	0.71	0.86	0.00	-0.28
2 sec	MEAN	Bottom	Standing	30	0.93	0.47	0.71	0.84	0.35	-0.25
2 sec	MEAN	Bottom	Lying	12	0.79	0.22	0.77	0.73	-0.79	-0.81
2 sec	MEAN	Bottom	Both	7	0.95	0.72	0.84	0.71	0.13	-0.37



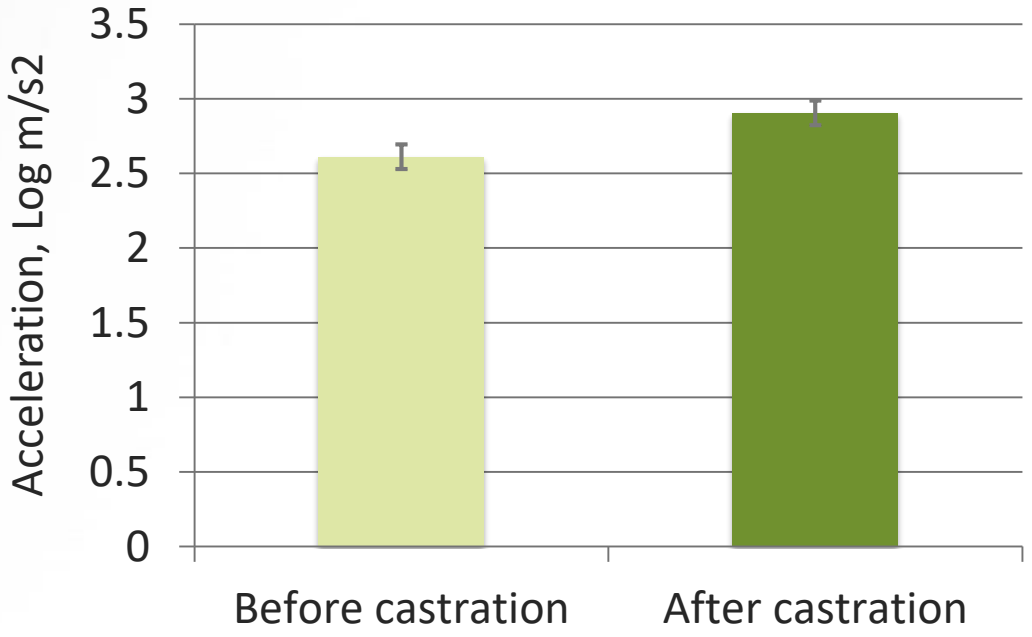
Conclusions

The information obtained from **visual observation** and the **accelerometers** is highly **correlated** (r = 0.94, $P < 0.01$)

- Place the accelerometer above the tail switch.
- Discard movements below the 80th percentile.
- Calculate overall acceleration over the sampling period.

Biological validation: Tail flick behavior after castration

- Accelerometers affixed above the tail switch of 14 bulls
- Two 20-min sampling periods: before and after castration



P = 0.03

- What, when and how?
- Monitoring animal location
- Monitoring animal activity
  - Grazing preference
  - Tail flick behaviour
  - Feed intake
- Pain assessment
- Temperament assessment
- Cognitive research
- Motivation state

Combination of multiple devices

Knowledge gap: Precision feeding largely unexplored in grazing herds

Objectives

To assess the effect of differing levels of intake on rumen fermentation profile, nutrient digestibility, methane emissions, and feeding behaviour in sheep

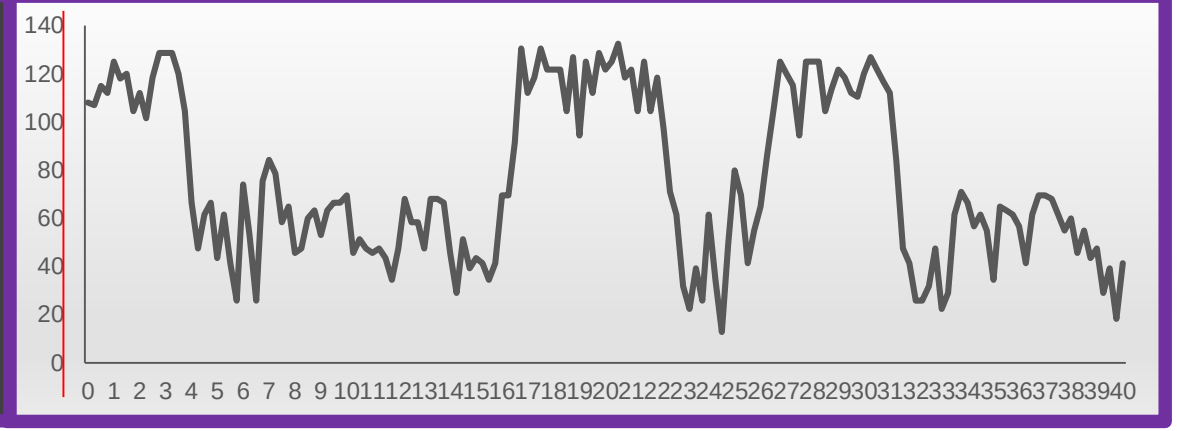
To evaluate existing methodologies on finding biomarkers of food intake

Use of accelerometers and sound recorders attached to a head harness to estimate feed intake.

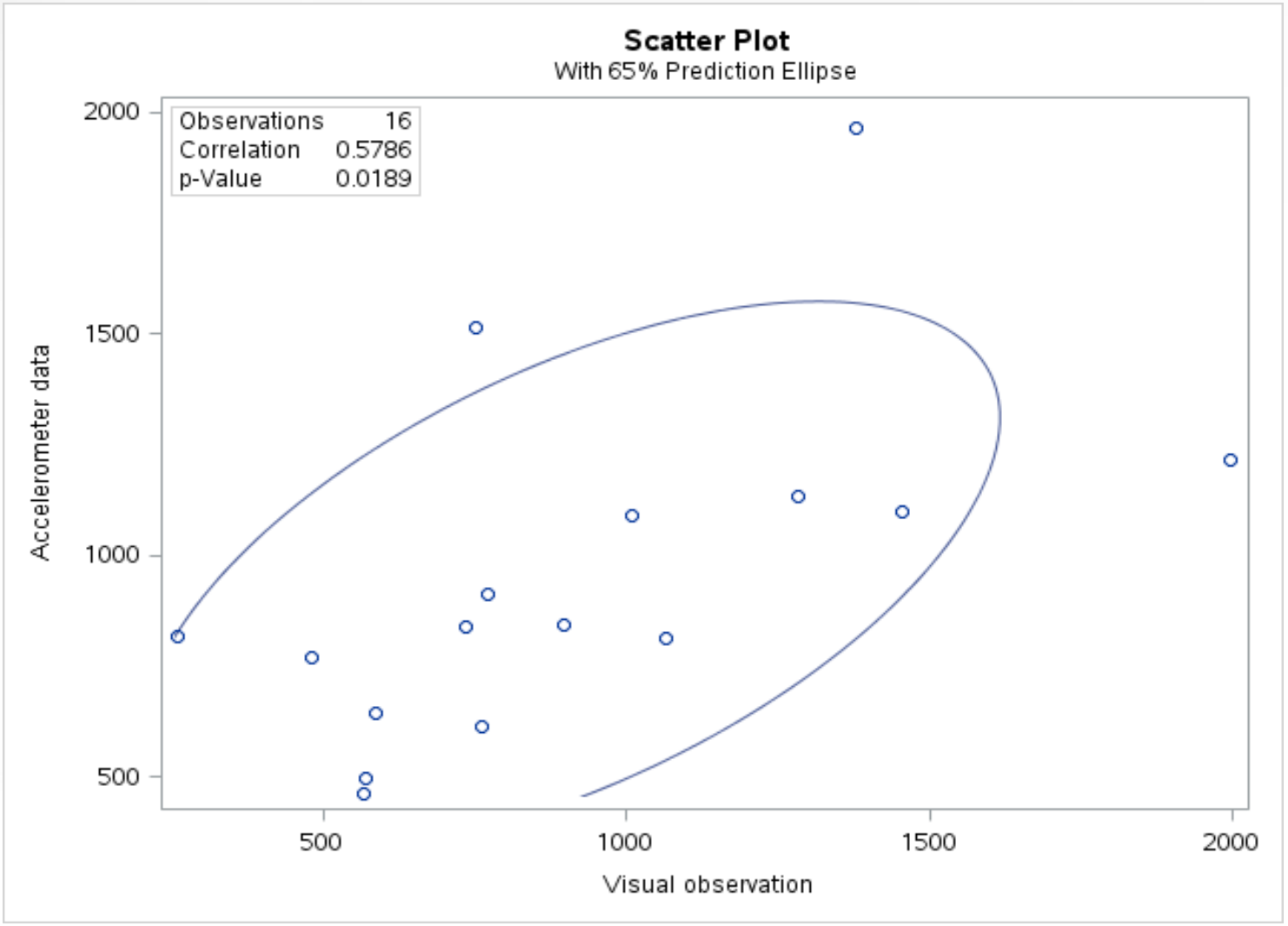
Video

Sound record

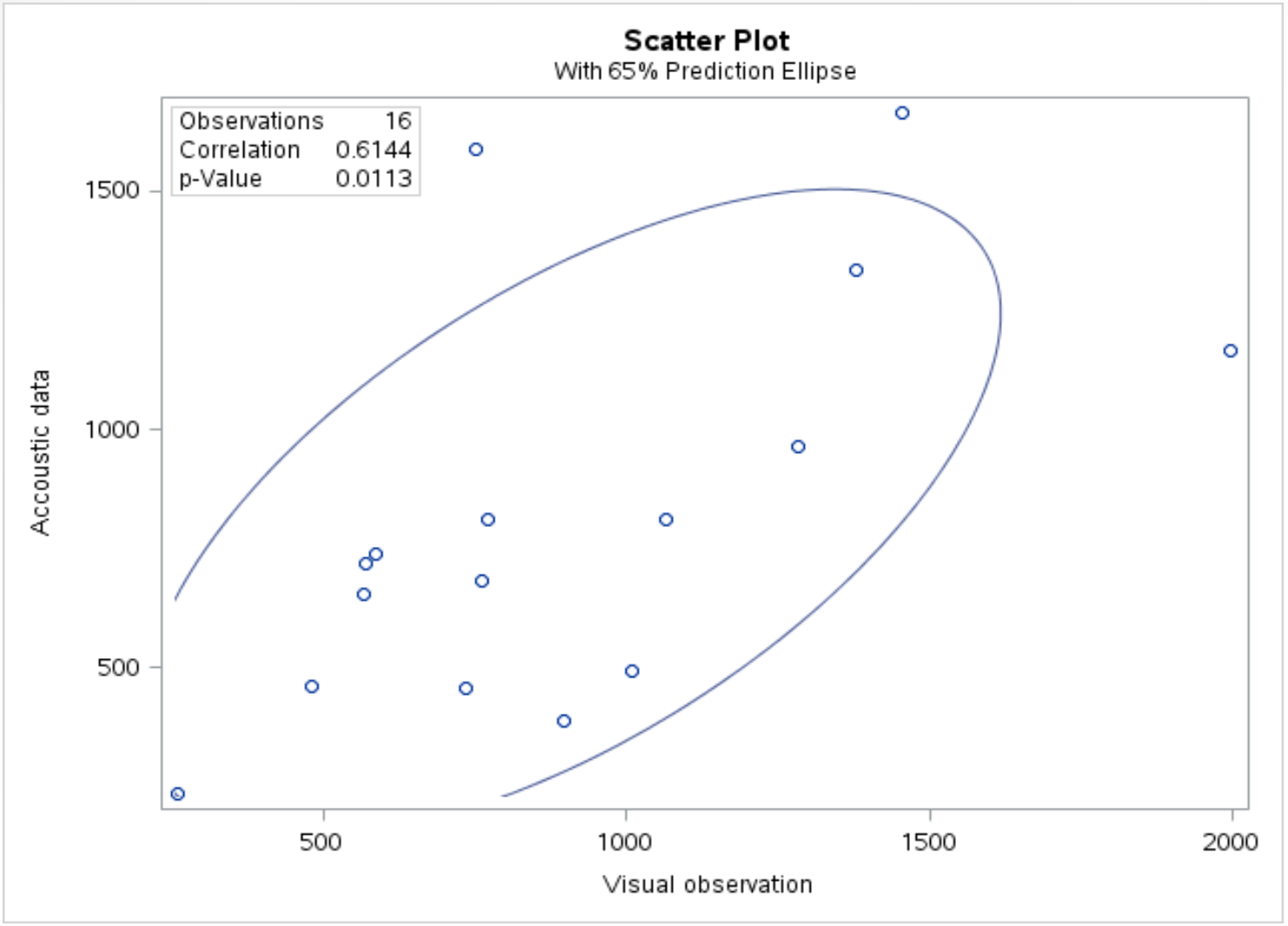
Head movement



Visual observation vs Accelerometer



Visual observation vs Accoustic data



Conclusions

Increased levels of intake have a measurable impact on diet

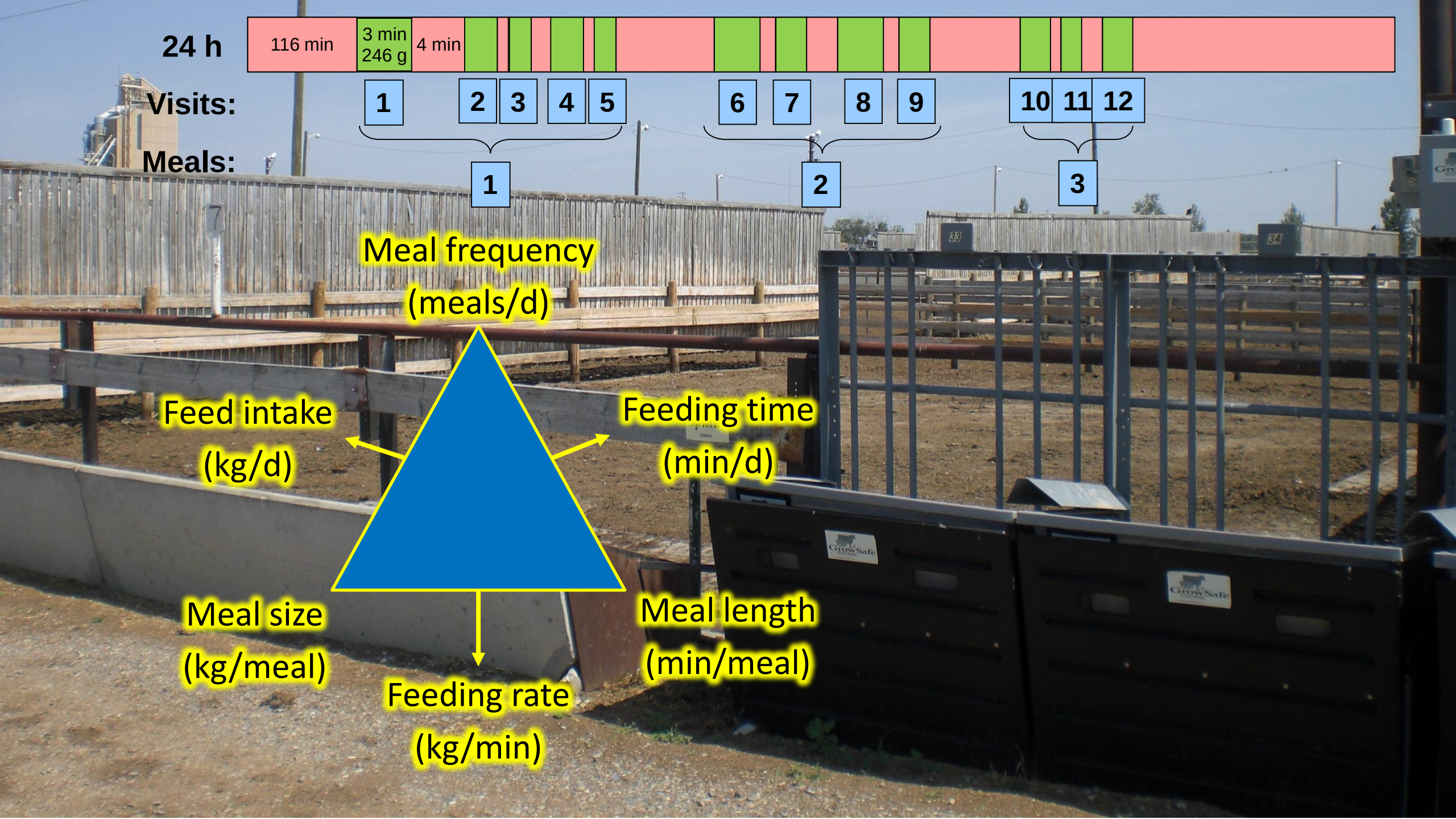
fermentation and digestibility

- ↓ Digestibility rate
- ↓ Methane emissions

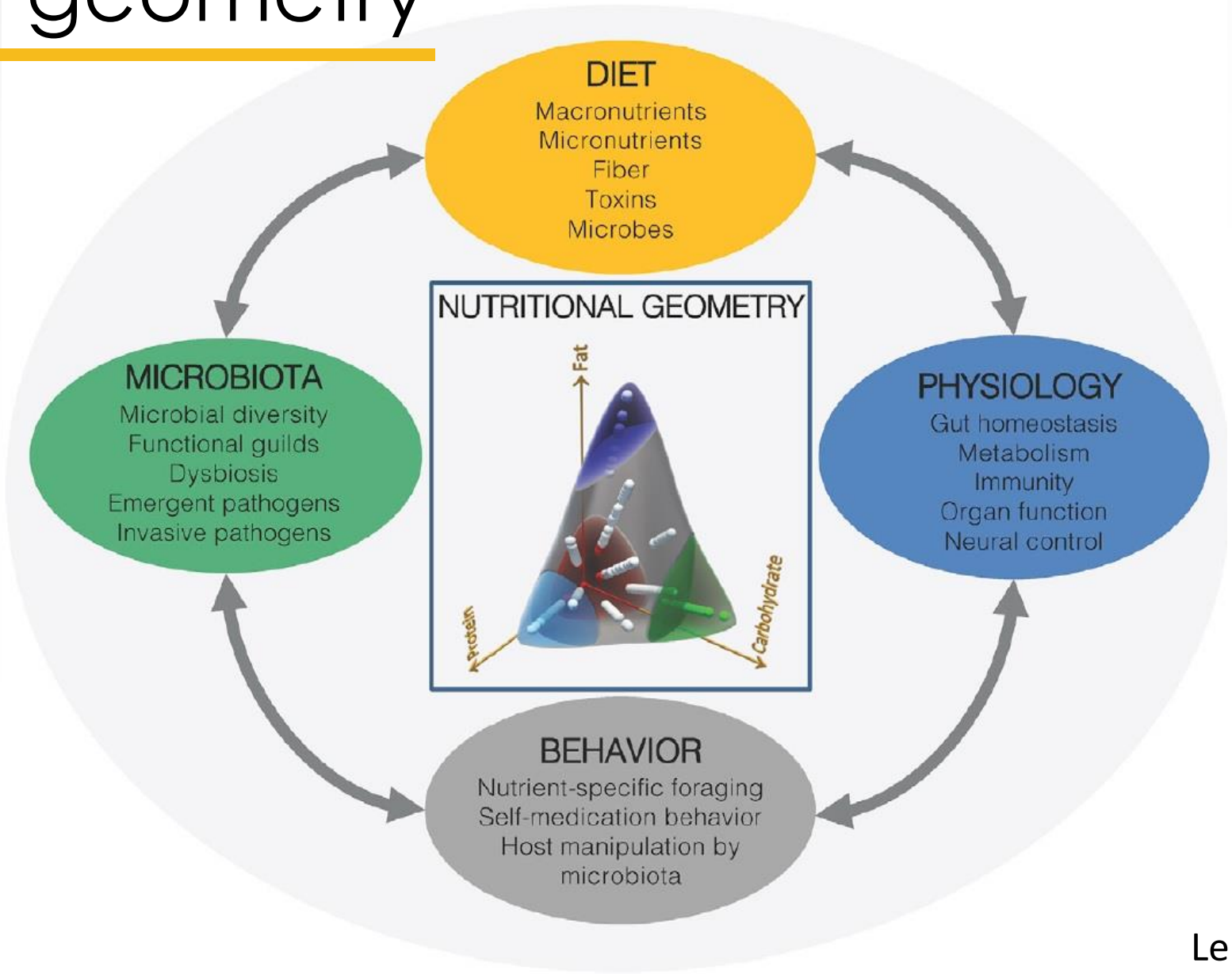
The combination of different data sets is a promising alternative to current methodologies to estimate feed intake

Tools to monitor feed intake

Tools to monitor feed intake


24 h
116 min
3 min
246 g
4 min
Visits:
1
2
3
4
5
6
7
8
9
10
11
12
Meals:
1
2
3
Meal frequency
(meals/d)
Feed intake
(kg/d)
Feeding time
(min/d)
Meal size
(kg/meal)
Meal length
(min/meal)
Feeding rate
(kg/min)

Nutritional geometry



Leulier et al., 2017

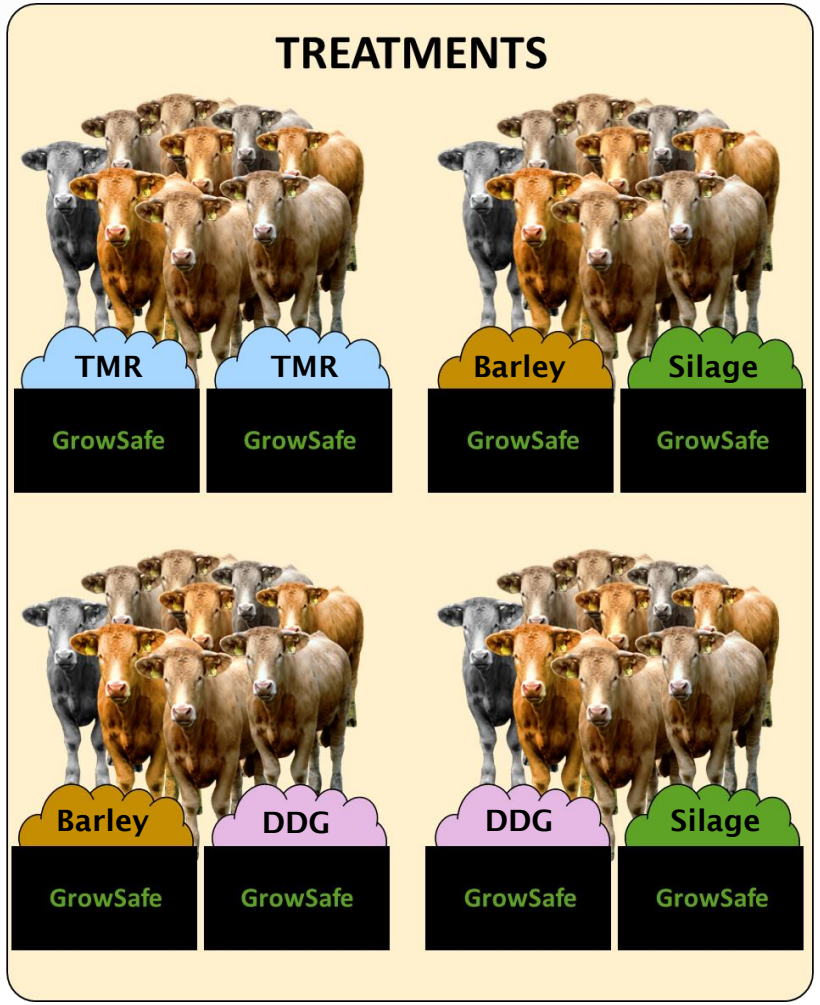
The effect of competition on feeding behaviour and growth performance of feedlot cattle

To assess the effects of the competitive interactions at the feed bunk on feeding behaviour and growth performance of beef cattle when offered a total mixed ration or different free-choice diets.

COMPETITIVE INTERACTIONS

Two feeding events from different heifers registered at the same feeding bunk within 5 sec.

At each competitive interaction, the outgoing and incoming animals were identified.



The effect of competition on feeding behaviour and growth performance of feedlot cattle

ACTIVITY

Amount of competitive interactions for each individual:

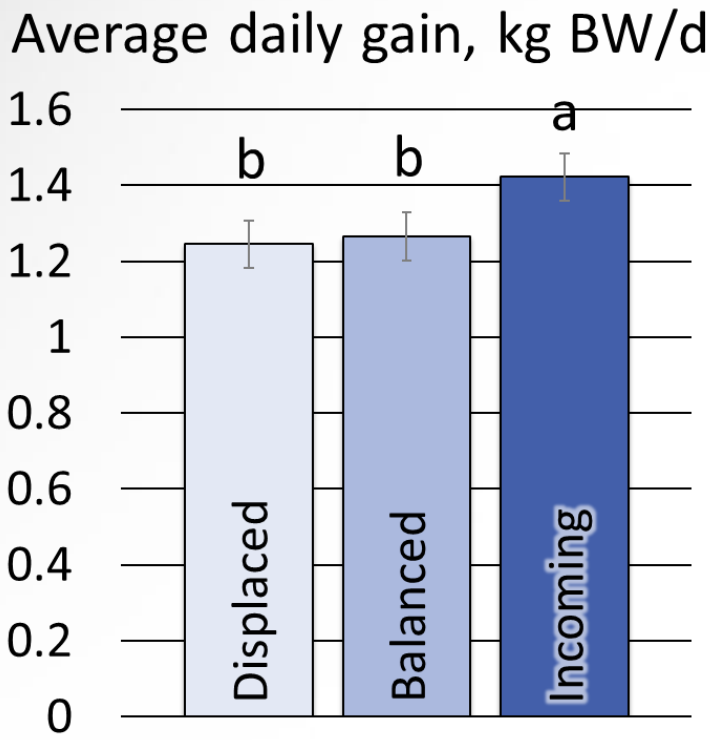
- **LOW** (bottom 15%)
- **MEDIUM**
- **HIGH** (top 15%)

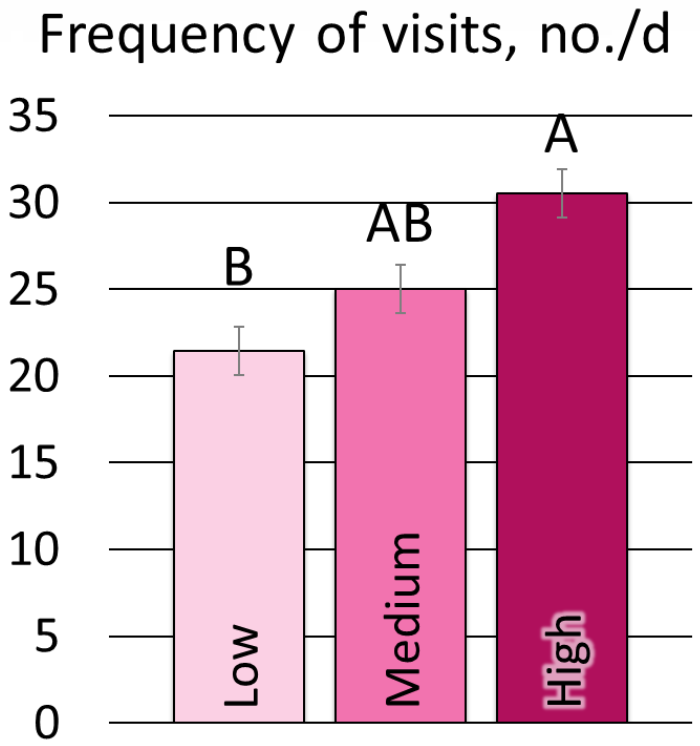
ENCOUNTERS OUTCOME RATIO

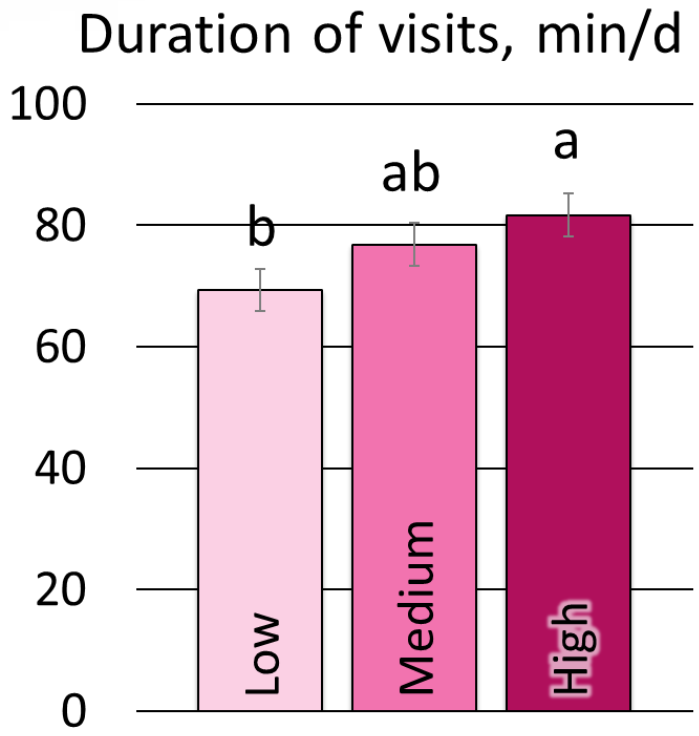
Depending on the incoming:outgoing ratio:

- **DISPLACED:** ratio ≤ 0.5
- **BALANCED:** 0.5 < ratio < 1.5
- **INCOMING**: ratio ≥ 1

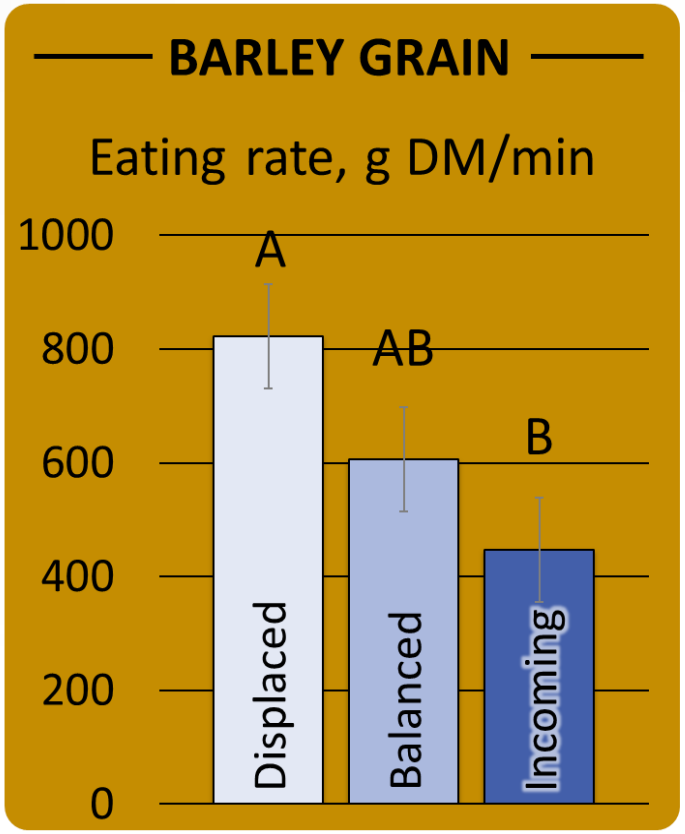
The effect of competition on feeding behaviour and growth performance of feedlot cattle

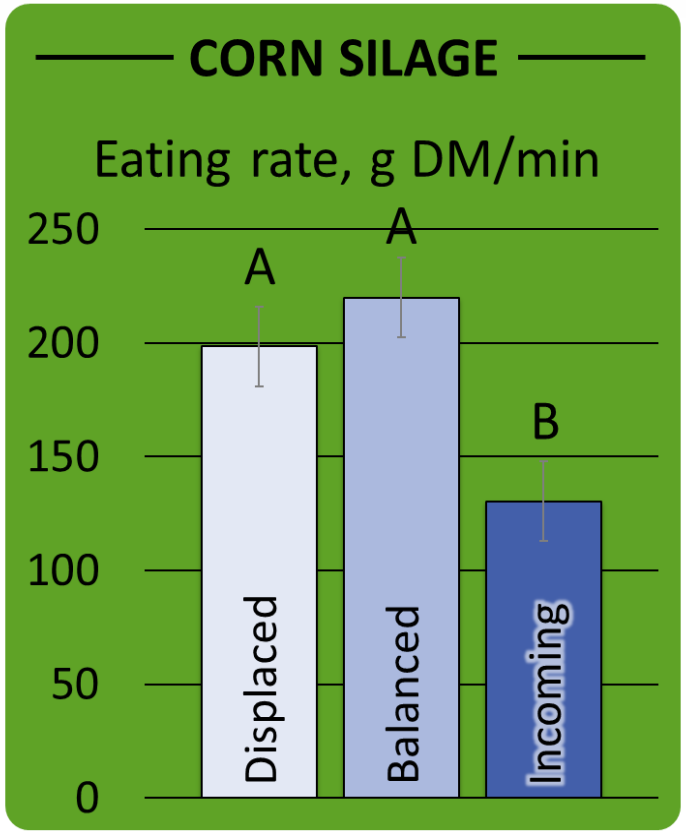






Effects of feed bunk competition on feeding behaviour and growth performance





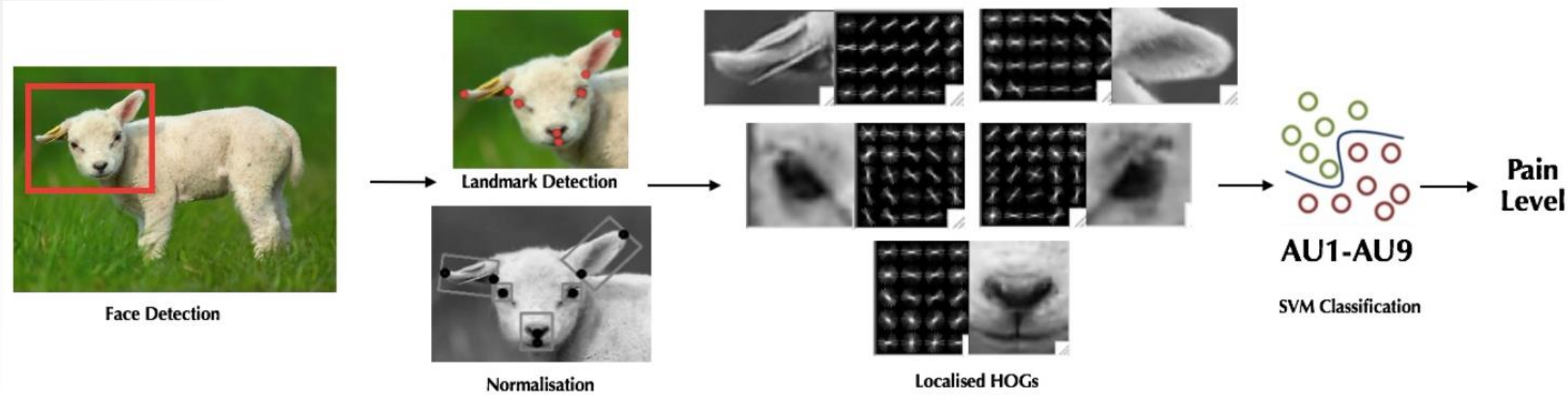
Outcomes

Competitive encounters at the feed bunk changed feeding behaviour towards different feed options and growth performance of beef heifers.

- What, when and how?
- Monitoring animal location
- Monitoring animal activity
  - Grazing preference
  - Tail flick behaviour
  - Feed intake
- Pain assessment
- Temperament assessment
- Cognitive research
- Motivation state

Signs of pain (the future?)

- Despite their different anatomy; mice, rats, rabbits, horses and sheep (including lambs) all pull a similar pain-face. They tighten their eyes, change the position of their ears and tense their mouths.

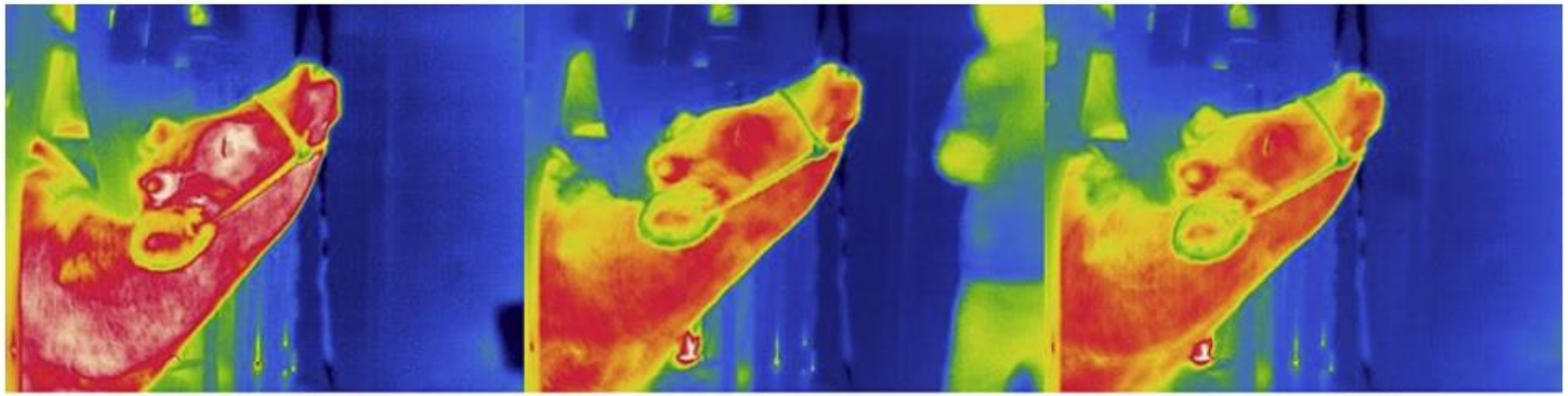


Lu et al., 2017


E60
33.4
16.4
OK

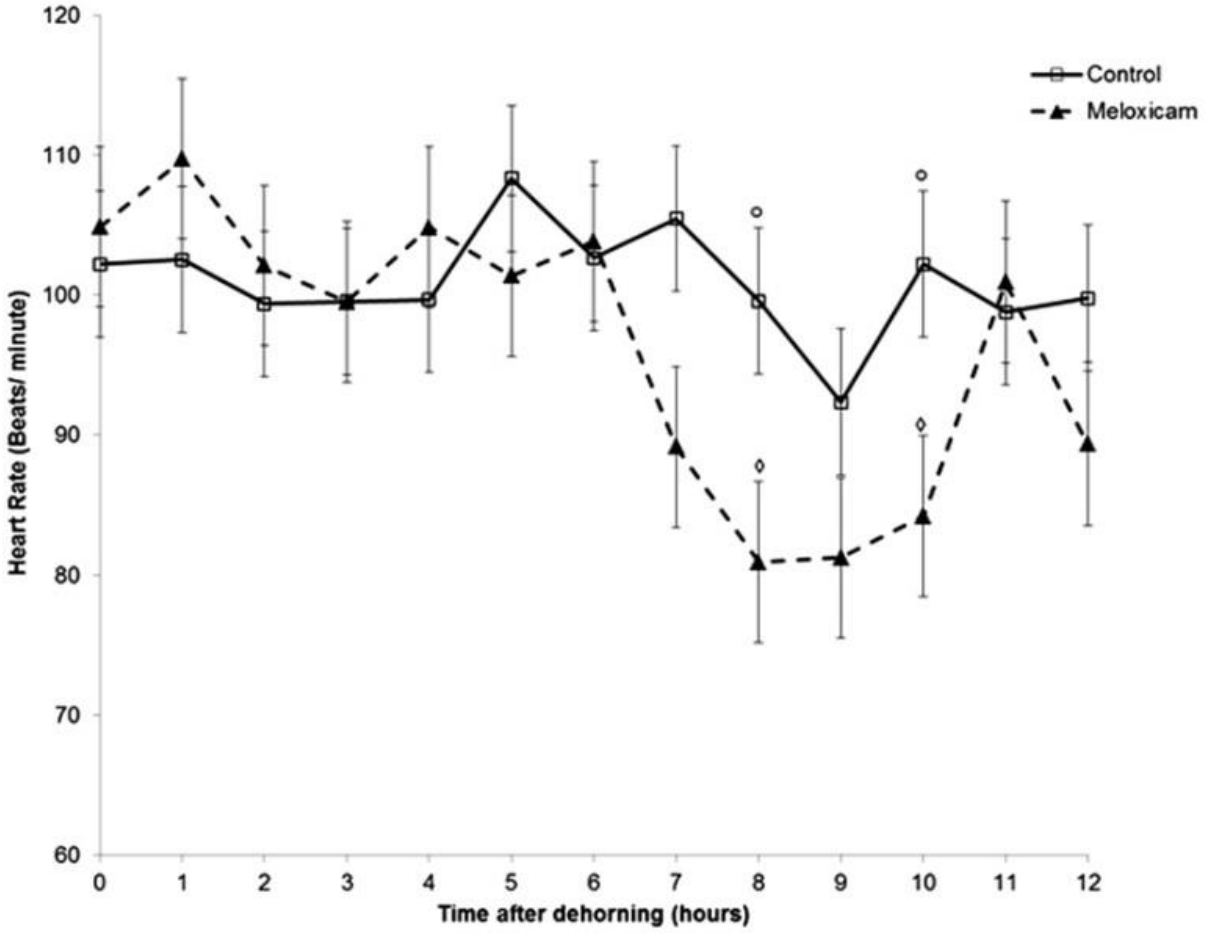
Infrared thermography during castration

- Colour changes likely indicate changes in peripheral perfusion associated with catecholamine release following castration



Coetzee, 2013 Vet Clin Food Anim

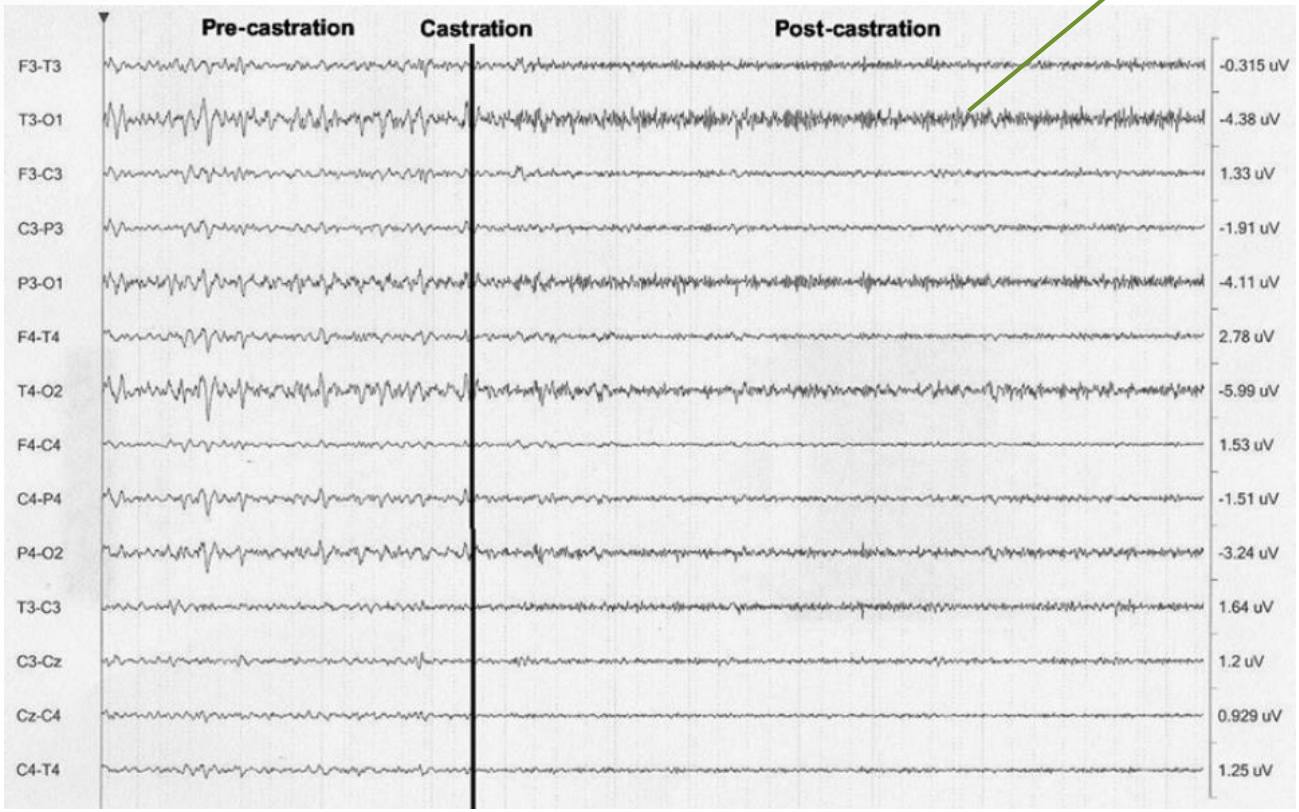
Heart rate after dehorning



Data from Coetzee et al., 2012, adapted by Stock et al., 2013 Vet Clin Food Anim

Electroencephalogram during castration

- Example of an EEG trace (30 s duration) illustrating brain electrical activity in a 6-week-old calf at castration



Greater frequency, lower amplitude

From Dr Luciana Bergamasco, Kansas State University, as published by Coetzee, 2013 Vet Clin Food Anim

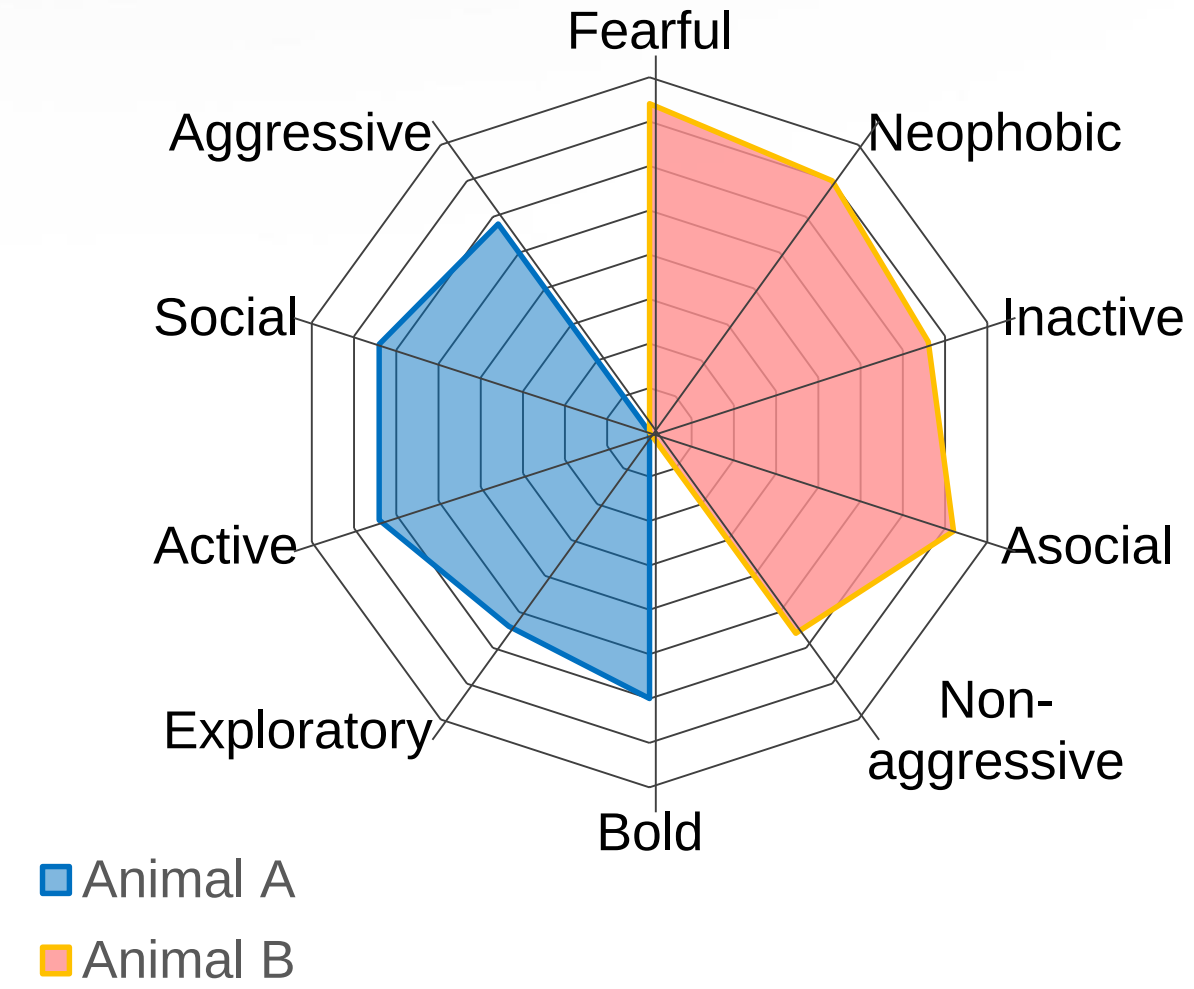

EXTECH
407790
Real Time Octave Band Analyzer
FREQ WGHT
TIME CONST
LEVEL
MEAS TIME
MEMORY
START STOP
Address
Cursor
PAUSE CONT
STORE
RECALL
ERASE


3
3x

- What, when and how?
- Monitoring animal location
- Monitoring animal activity
  - Grazing preference
  - Tail flick behaviour
  - Feed intake
- Pain assessment
- Temperament assessment
- Cognitive research
- Motivation state

What is temperament?

- Defined as a trait that is individual to each animal
- Capable of influencing an animal's response to handling (Sebastian et al. 2011)
- Stable over time and repeatable from one situation to the next (Colditz et al. 2016)
- Influenced by many factors (Grandin. 1997)
- Moderately heritable (Hasktell et al. 2014)



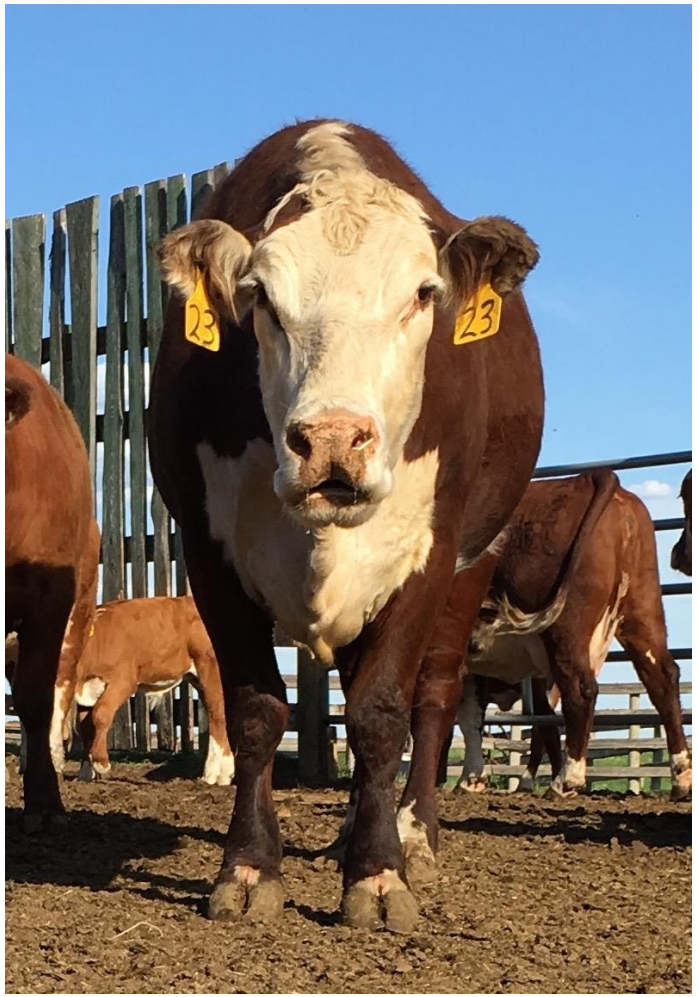
Hemsworth and Coleman, 2011. Human-Livestock interactions

The effects of temperament on…

Productivity

- Cattle that remained calm during weighing and handling had higher ADG (Muller et al. 2006)
- Greater risk of causing injury to themselves or other animals

(Haskell et al. 2014)



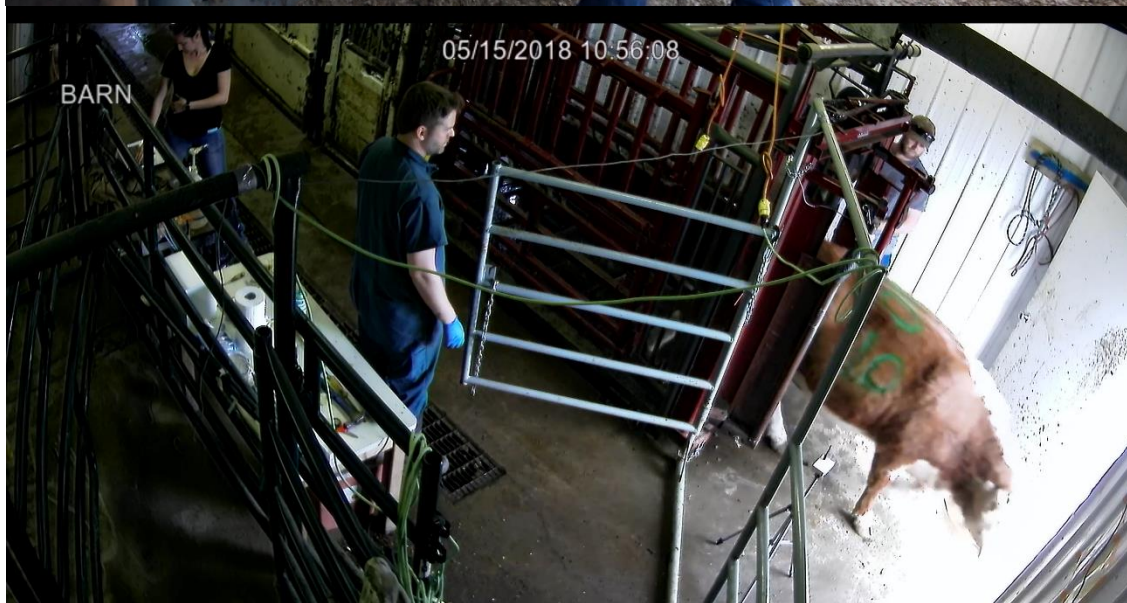
The effects of temperament on…

Immune function

- Cascade effect: Higher levels of cortisol in excitable animals→ chronic stress → Reduced immune function → Increased susceptibility to disease

Measuring Temperament

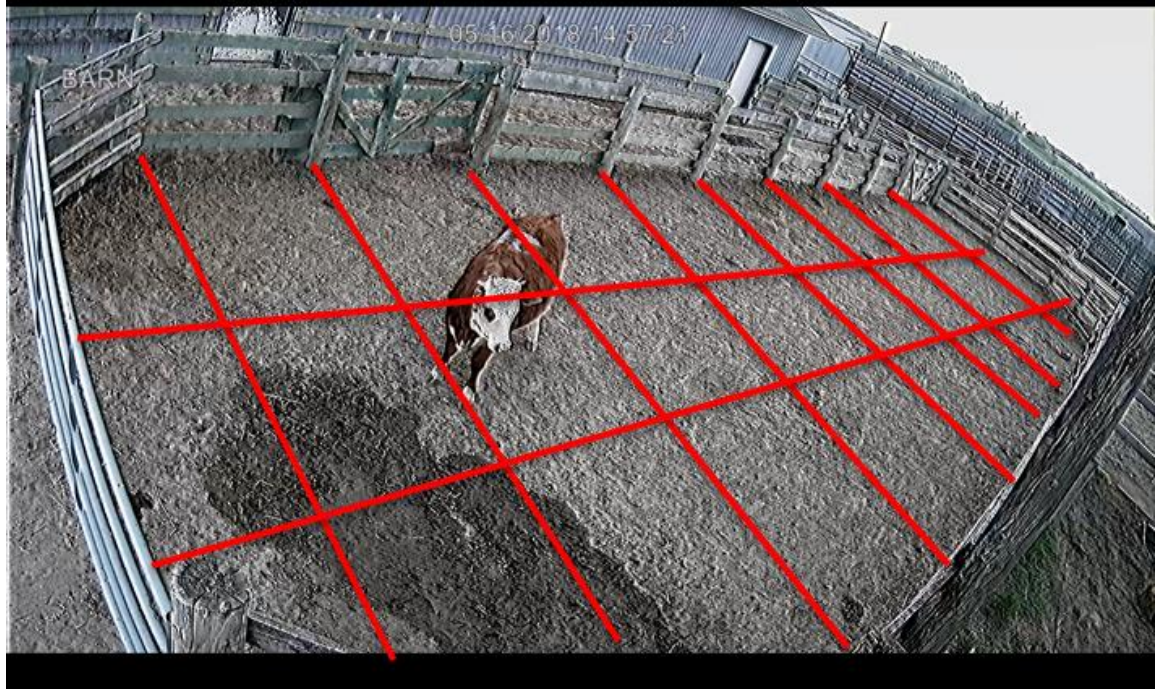
- Chute score: Strain gauges connected to head gate (Stookey et al. 1994).
- Human reactivity test: Scale of 1 (highly reactive) to 5 (unreactive).
- Flight speed: Laser beams (Burrow. 1988)



Measuring Temperament

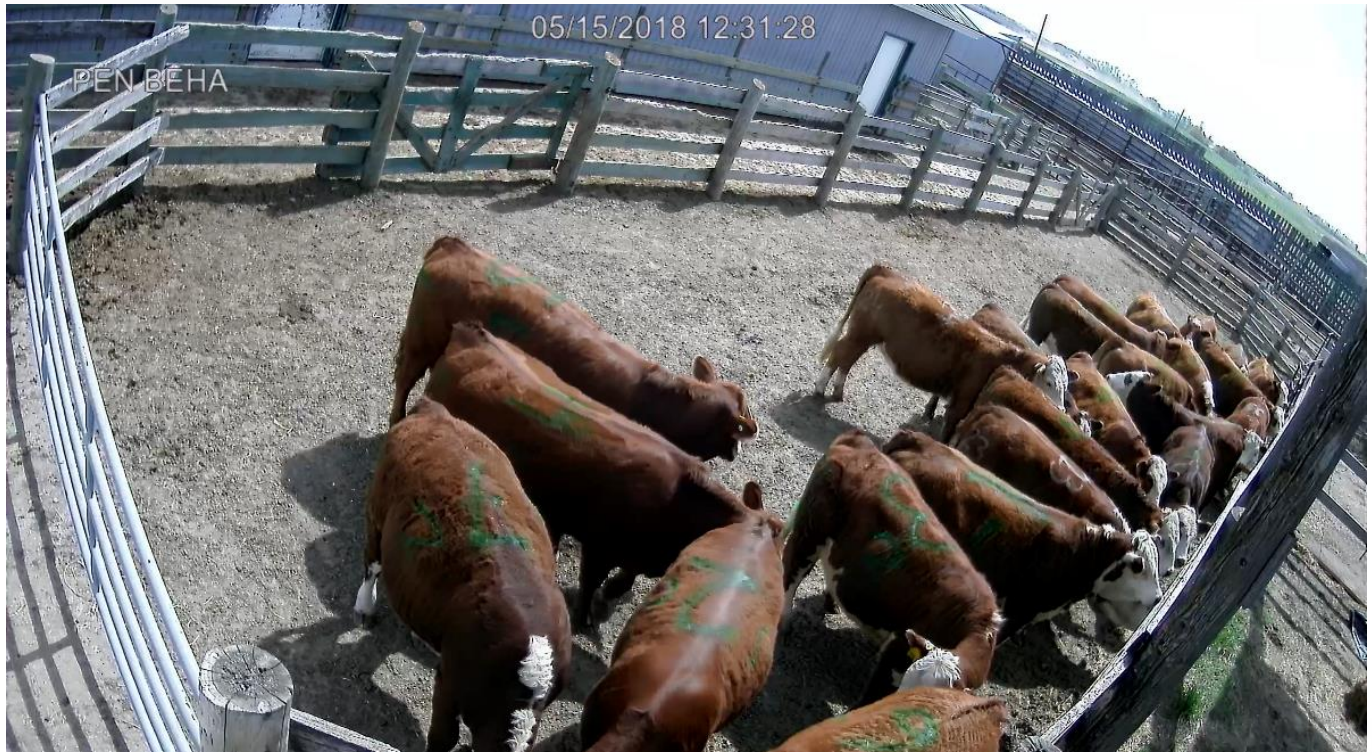
- Novel object test: Recorded heifers that got close or stayed away.

- Open-field test: Number of squares visited, lines crossed, time spent walking vs running and in center vs squares



Dominance status

- Behaviors observed:
  - Fighting
  - Head butting
  - Displacement
  - Chasing
  - Chasing-up
  - Licking
  - Horning
- Recorded acting and receiving animal of each dyadic interaction → Dominant / Balanced / Subordinate



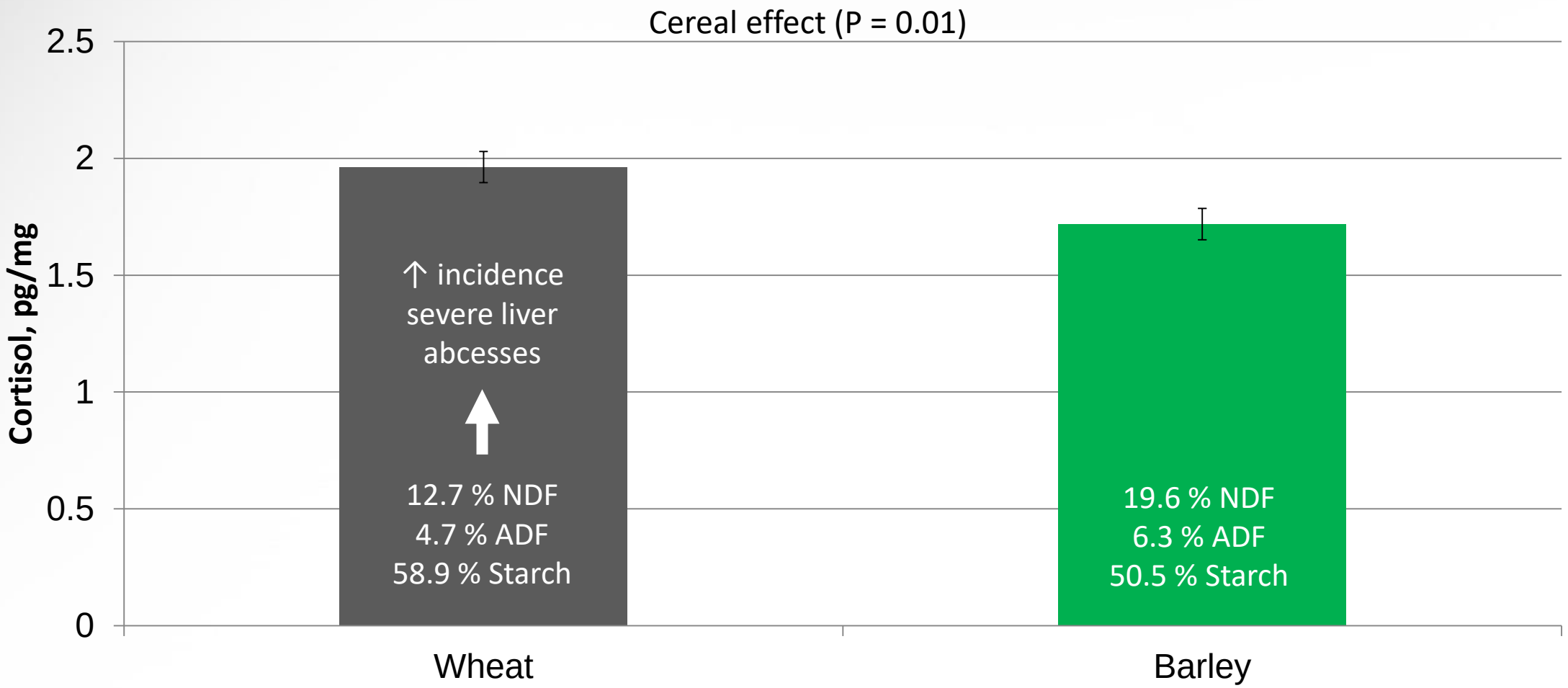
Effect of grain type and processing index on growth performance, carcass quality, feeding behavior, and stress response of feedlot steers[1]

D. Moya,*[2] M. L. He,*†[2] L. Jin,* Y. Wang,*
G. B. Penner,† K. S. Schwartzkopf-Genswein,* and T. A. McAllister*[3]

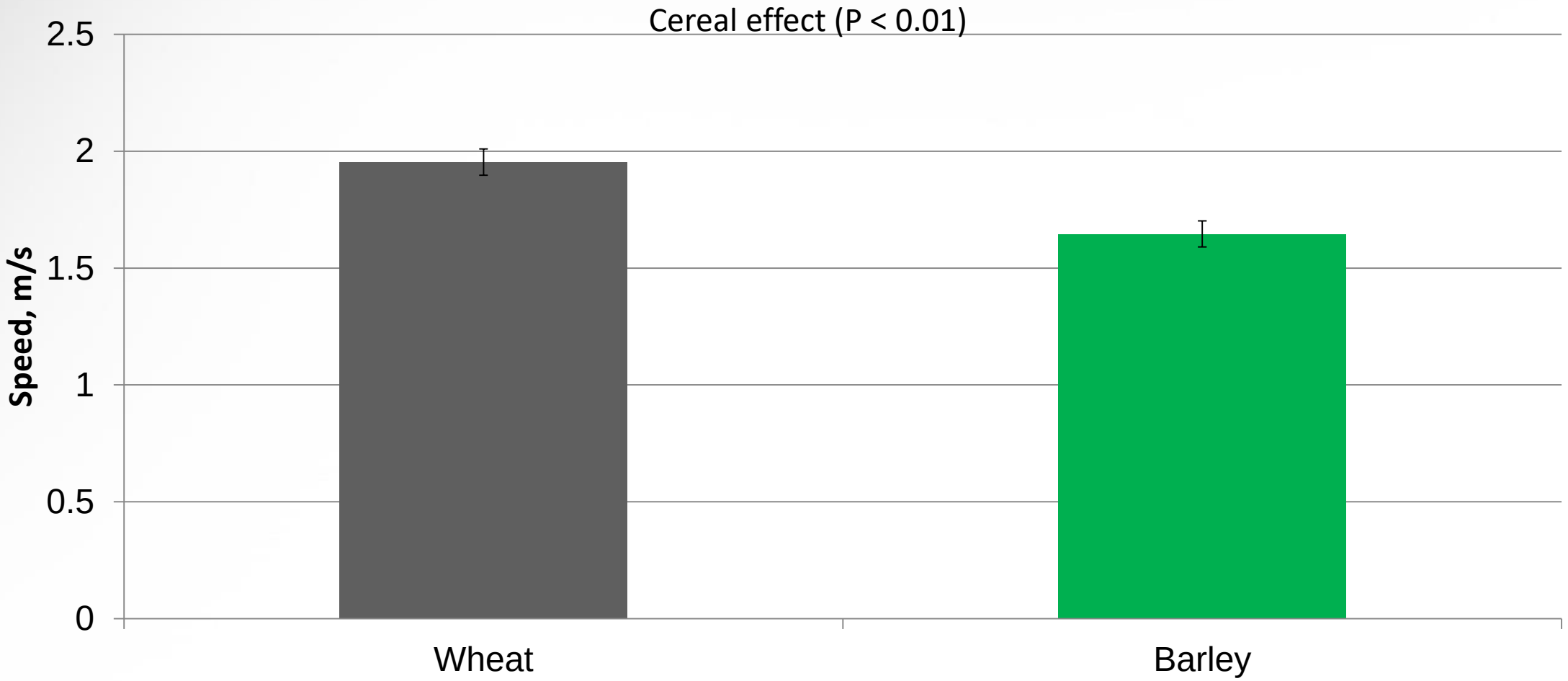
*Agriculture and Agri-Food Canada Research Centre, Lethbridge, AB T1J 4B1, Canada;
and †Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK, S7N 5A8 Canada

- The use of wheat instead of barley reduced DMI, frequency of visits to the feed bunk, and time spent at the feed bunk.
- These differences did not have any effect on growth performance or carcass quality, but…
- …it did have an impact on animal welfare

Hair cortisol



Exit speed



- What, when and how?
- Monitoring animal location
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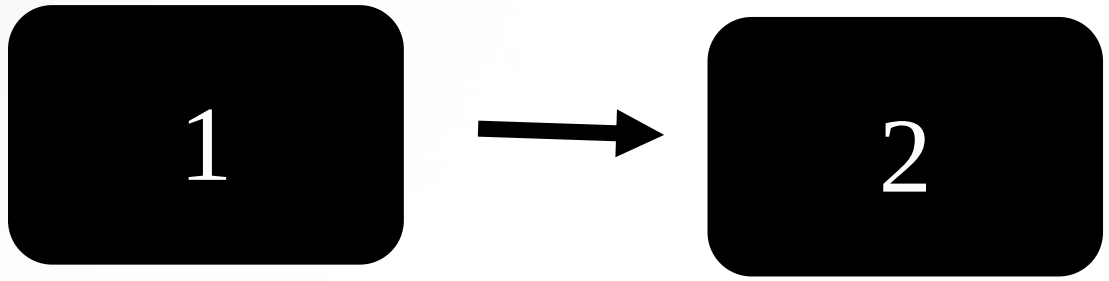
  - Grazing preference
  - Tail flick behaviour
  - Feed intake
- Pain assessment
- Temperament assessment
- Cognitive research
- Motivation state

Cognitive research has the potential to highlight mismatches between current husbandry practices and adaptive abilities of livestock (adaptation to new facilities, feed bunks, pen mates…)

Other links to cognitive function

Parasitic infestation/Immune status

- Appears to have a detrimental effect on visual attention, learning and memory
- Numbers 1-4: When 1 followed by 2 → PRESS button
- Poor performance on the attention task showed a significant association with parasite status



Pabalan et al., 2018


Visual attention
and parasite
burden in sheep?

Physical cognition

COGNITIVE TRAIT

Object permanence: Notion that objects continue to exist when they move out of the visual field

IMPLICATIONS

Perceived predictability of environment (housing)

Nawroth et al., 2015

Physical cognition

COGNITIVE TRAIT

Reasoning/Inferences:
Establishment of an association between a visible and an imagined event.

IMPLICATIONS

Perceived predictability of environment (housing);
Complexity of cognitive enrichment

Nawroth et al, 2015

Physical cognition

COGNITIVE TRAIT

Tool use: Manipulation of objects to reach a goal

IMPLICATIONS

Complexity of cognitive enrichment

Jelbert et al, 2014

- What, when and how?
- Monitoring animal location
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The **motivational state** of an animal is a combination of the levels of all **causal factors** (genes, physiology, and experience/learning/memory)

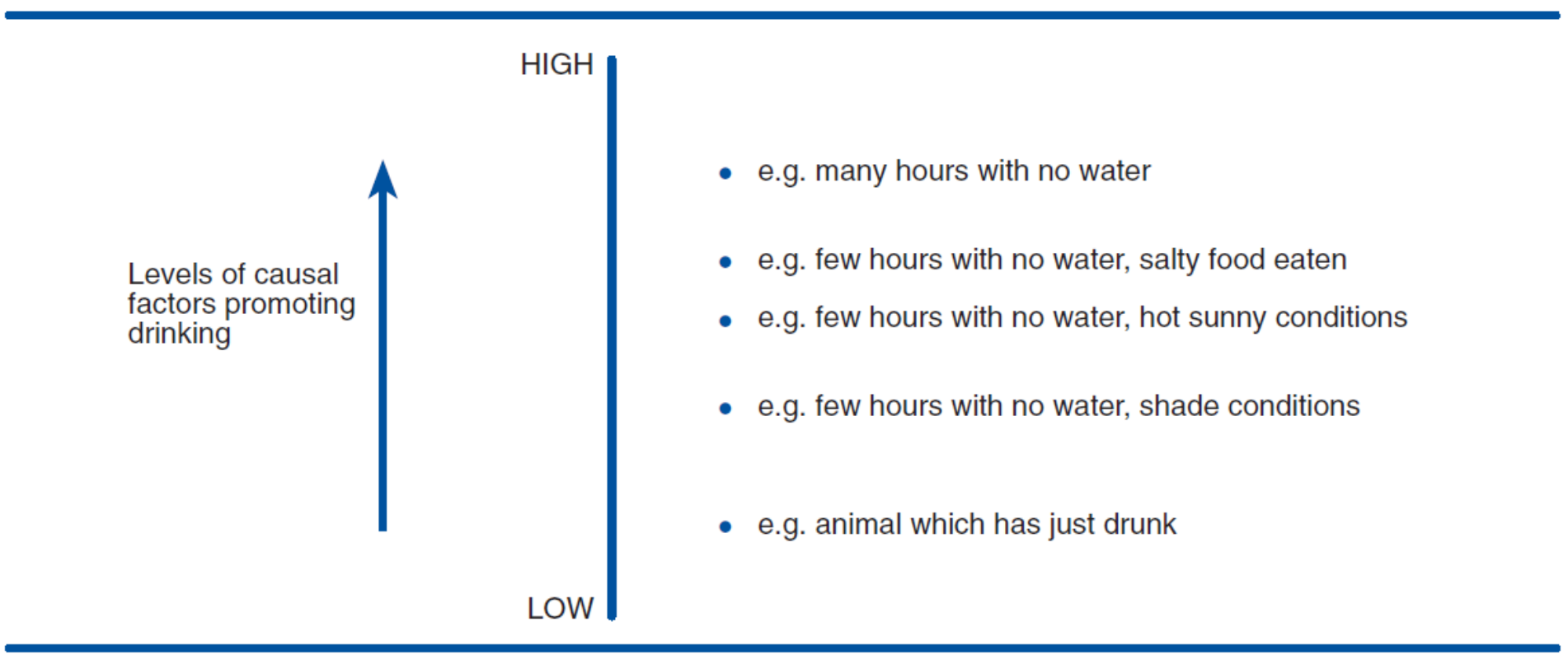


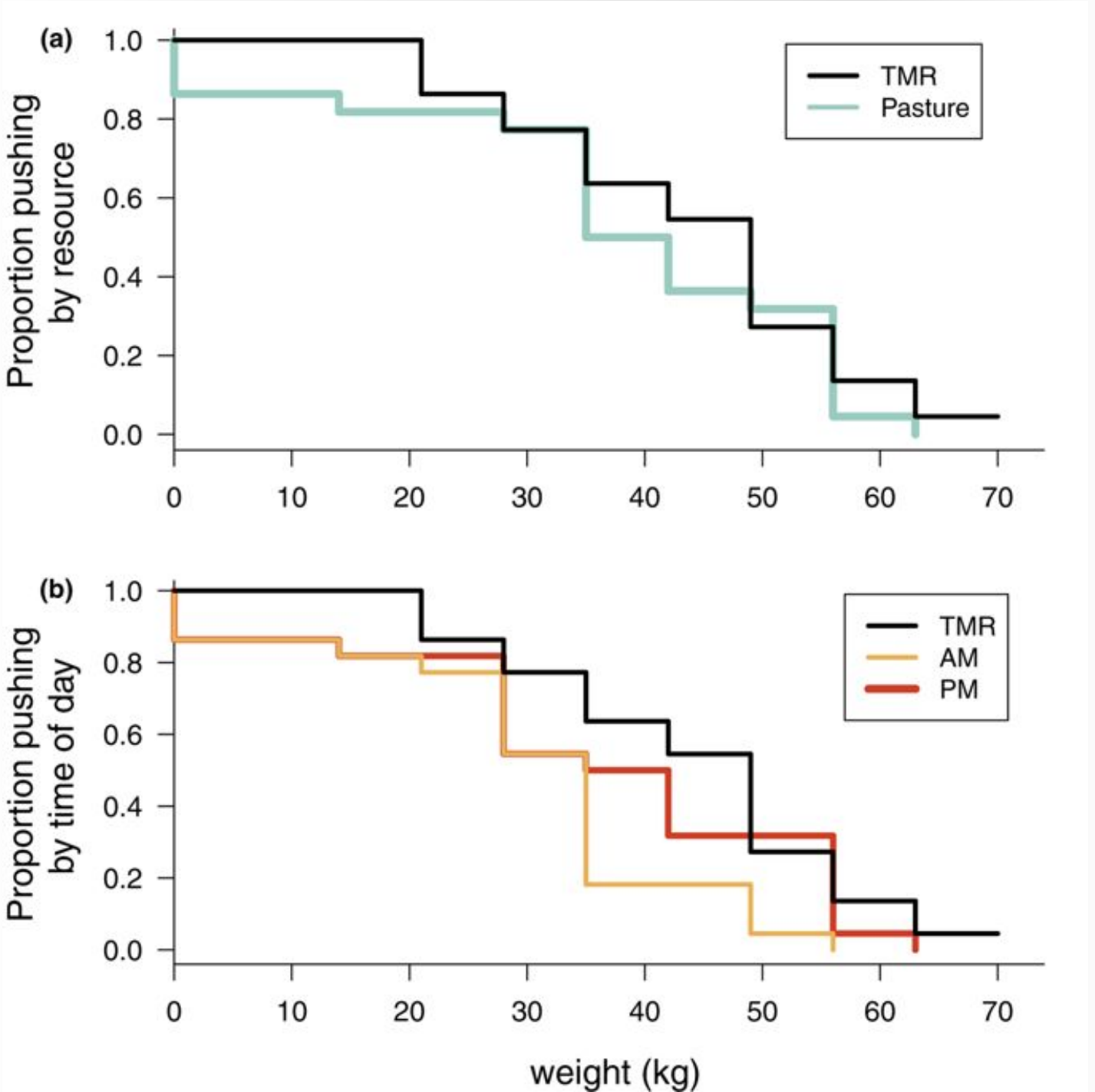
Fig. 4.2. Levels of causal factors that promote a particular action vary over a range, and the state of the animal can be described in terms of these.

Measuring motivation: operant conditioning

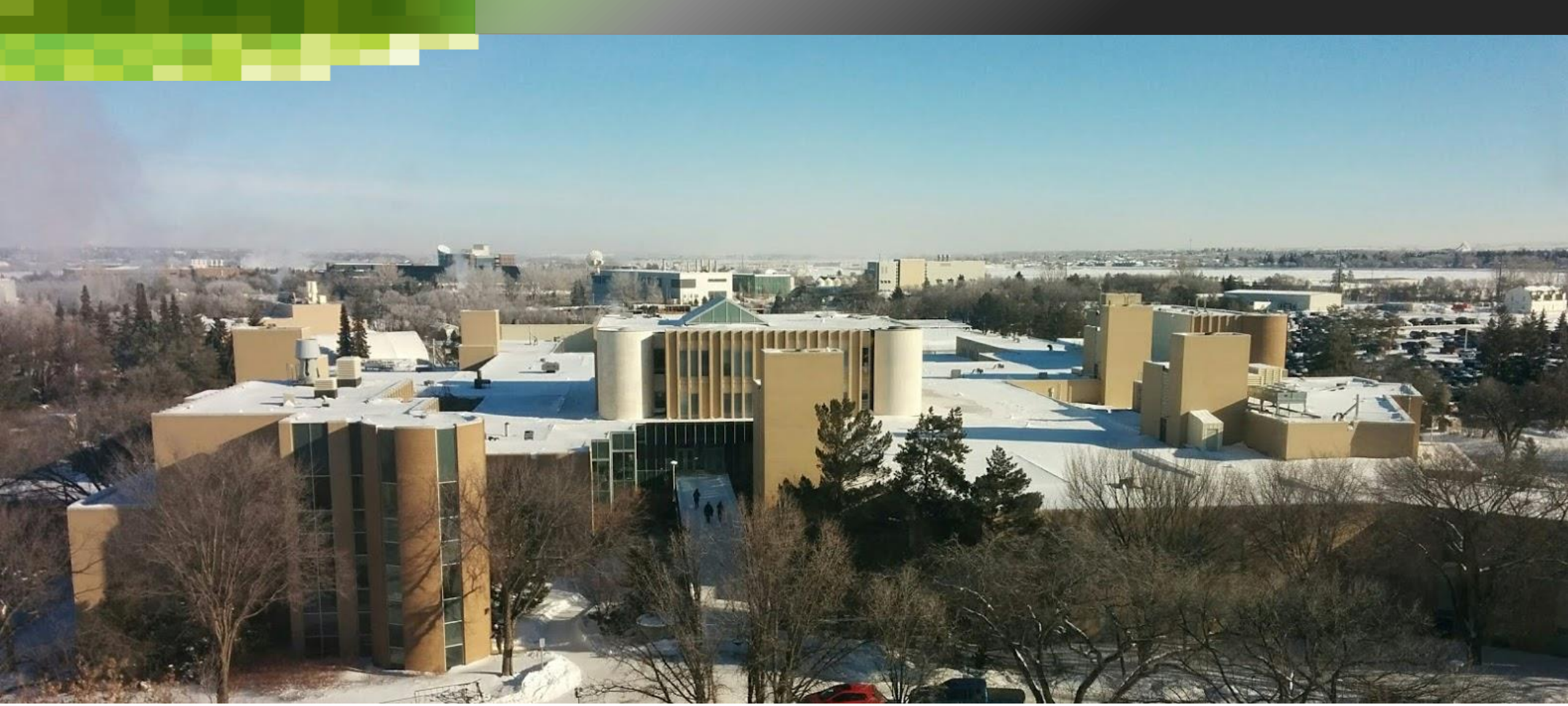
Once animals have learned to perform an operant task to obtain access to a resource, the ‘work’ required for each access can be increased.

von Keyserlingk et al., 2017

- Dairy cows are as motivated to access pasture as they are to eat fresh feed two hours after milking.
- Results suggest that motivation to access pasture was not driven by hunger, but rather motivation to be outside.
- Further research could investigate the nature of this motivation (e.g. providing grazing opportunities vs. outdoor access only).



von Keyserlingk et al., 2017



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USASK.CA/WCVM