The Role of Electroencephalography in Animal Welfare Research

Craig Johnson

Massey University

AWSBC
animal welfare science and bioethics centre

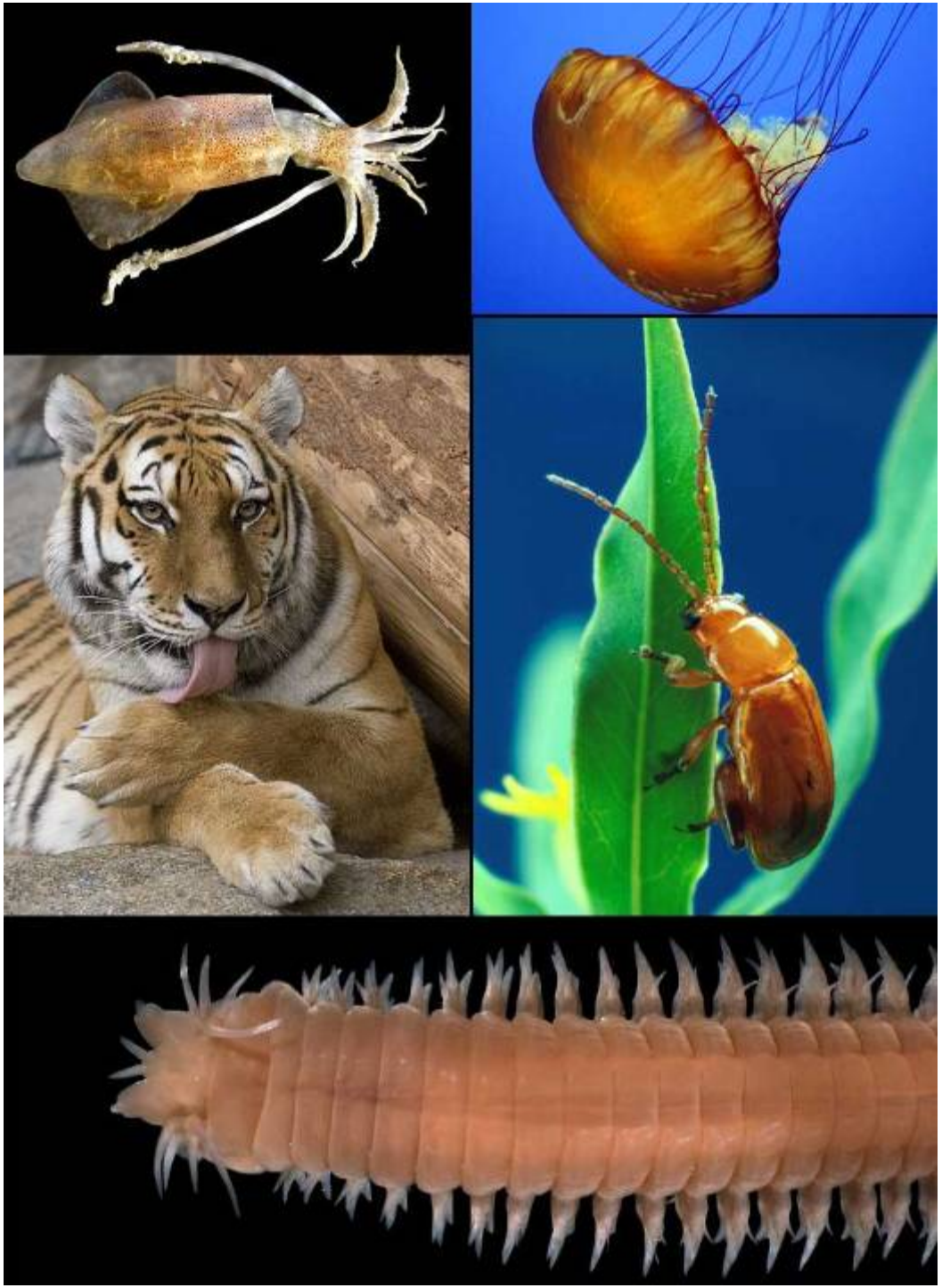
Massey University Comparative Analgesia Group
"Team Ouch"

The Plan for Today

What Things Interest Me
How Do We Analyse EEGs?
A Brief History of my Research
Examples of Our Work

My Interests

Animal Welfare
Physiology of Pain
Comparative Analgesia
Veterinary Anaesthesia



What is an Animal?

Animals are a major group of multicellular, eukaryotic organisms of the kingdom Animalia or Metazoa

What is an Animal?

Animal

(a) Means any live member of the animal kingdom that is:

(i) A mammal; or

(ii) A bird; or

(iii) A reptile; or

(iv) An amphibian; or

(v) A fish (bony or cartilaginous); or

(vi) Any octopus, squid, crab, lobster, or crayfish (including freshwater crayfish); or

(vii) Any other member of the animal kingdom which is declared from time to time by the Governor-General, by Order in Council, to be an animal for the purposes of this Act

Animal Welfare Act 1999 (NZ)

What is an Animal?

Animal

(b) Includes any mammalian fetus, or any avian or reptilian pre-hatched young, that is in the last half of its period of gestation or development; and

(c) Includes any marsupial pouch young

Animal Welfare Act 1999 (NZ)

What is an Animal?

The Key Concept is the Assumed Ability to Suffer

That is:

A Noxious Stimulus May Have a Negative Impact on the Animal's Welfare

What is an Animal?

An Animal is an organism of a sufficiently complex species and stage of its life cycle that it has the capacity to suffer

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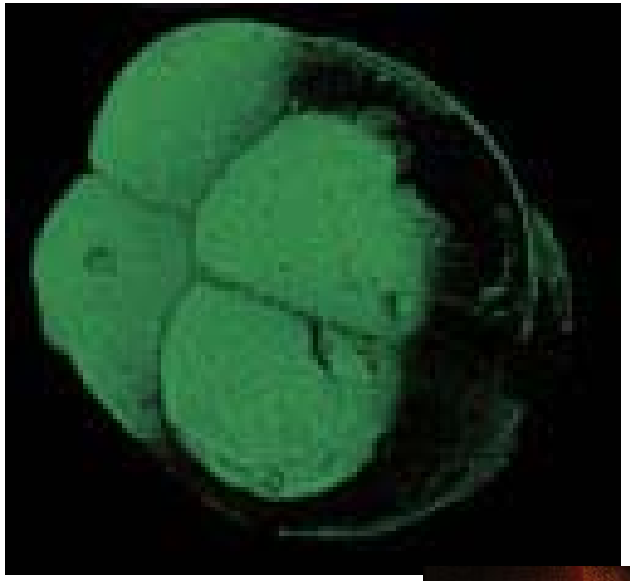
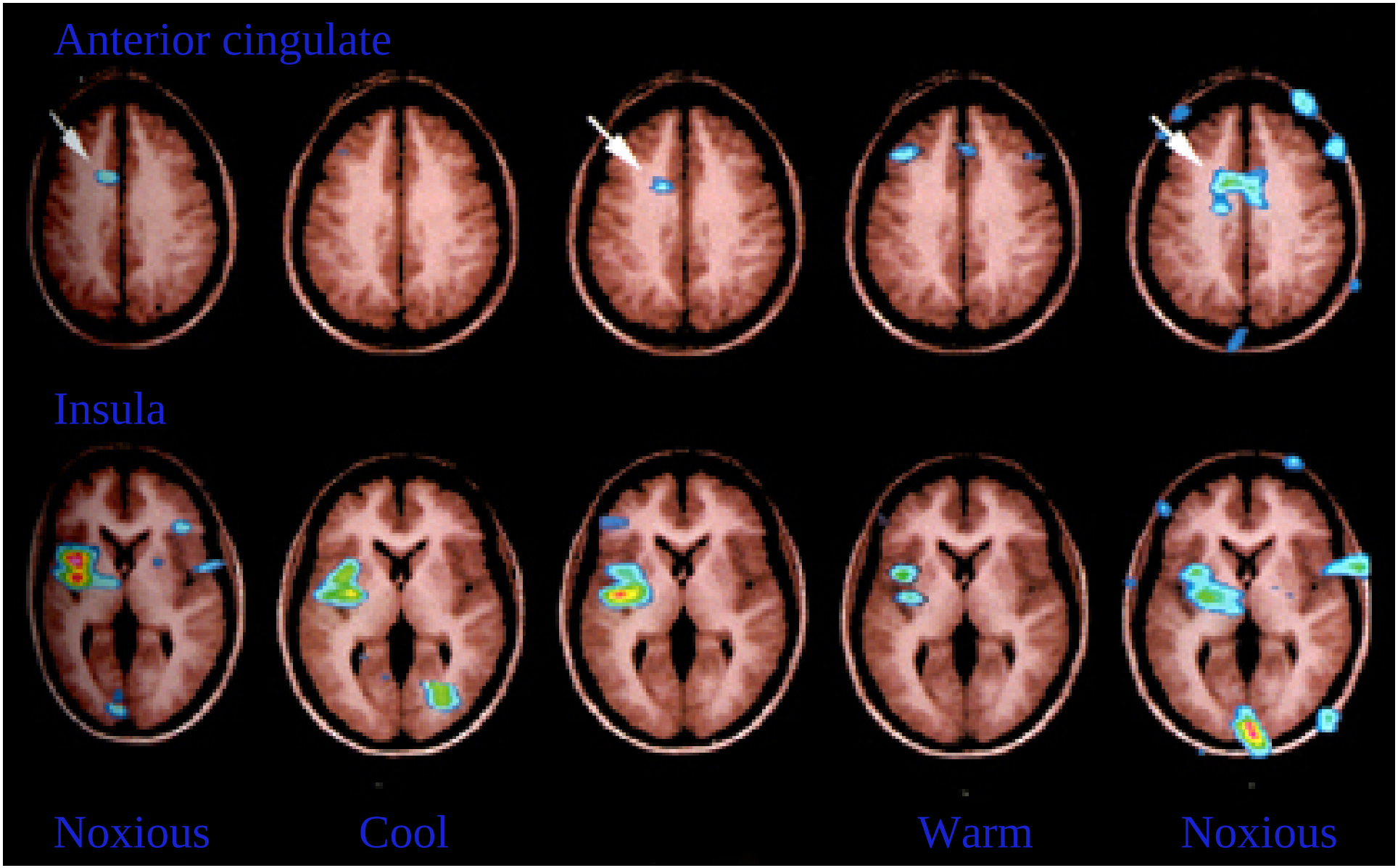
Where Are The Limits of Pain?

Where Are The Limits of Pain?

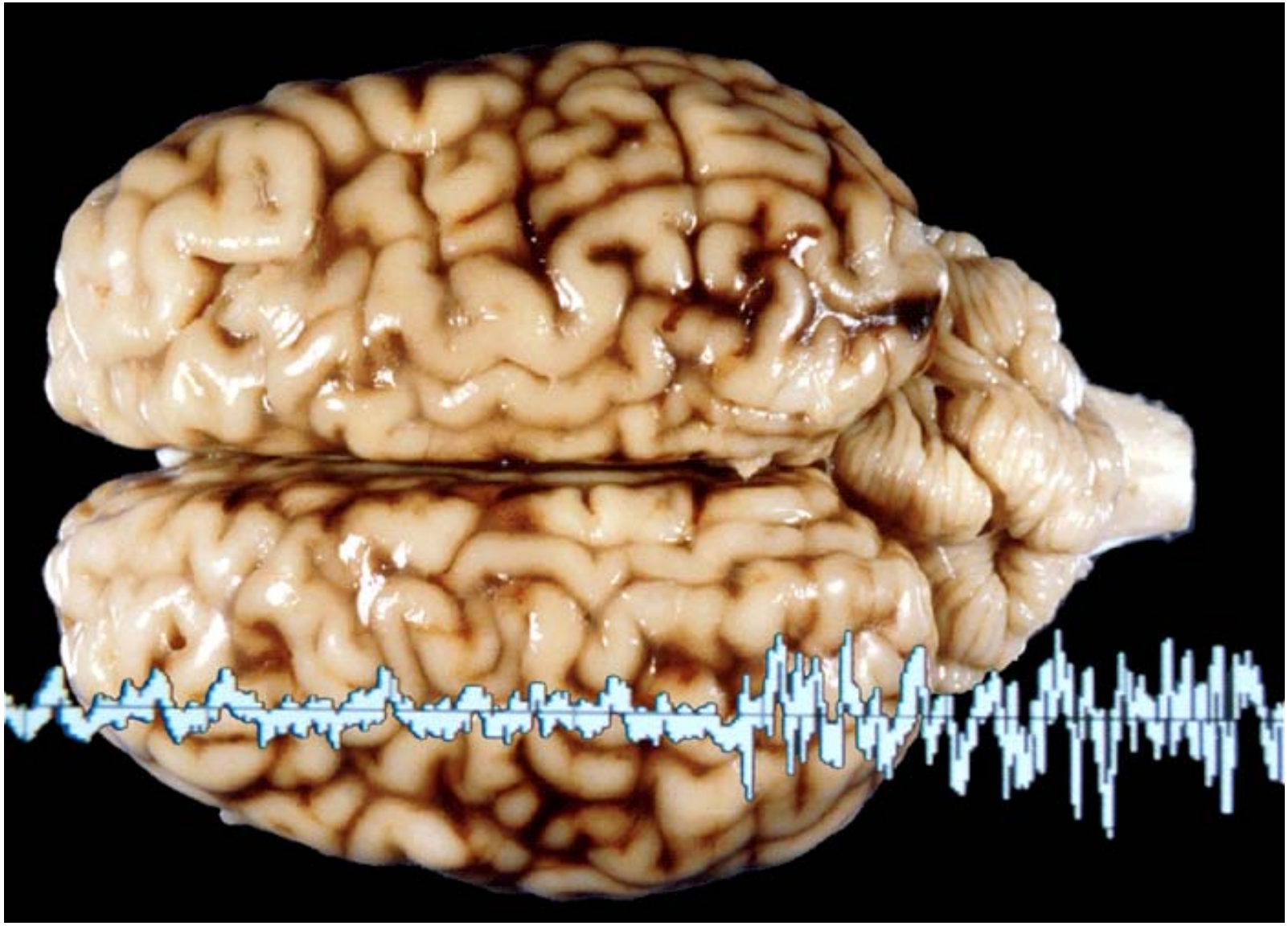


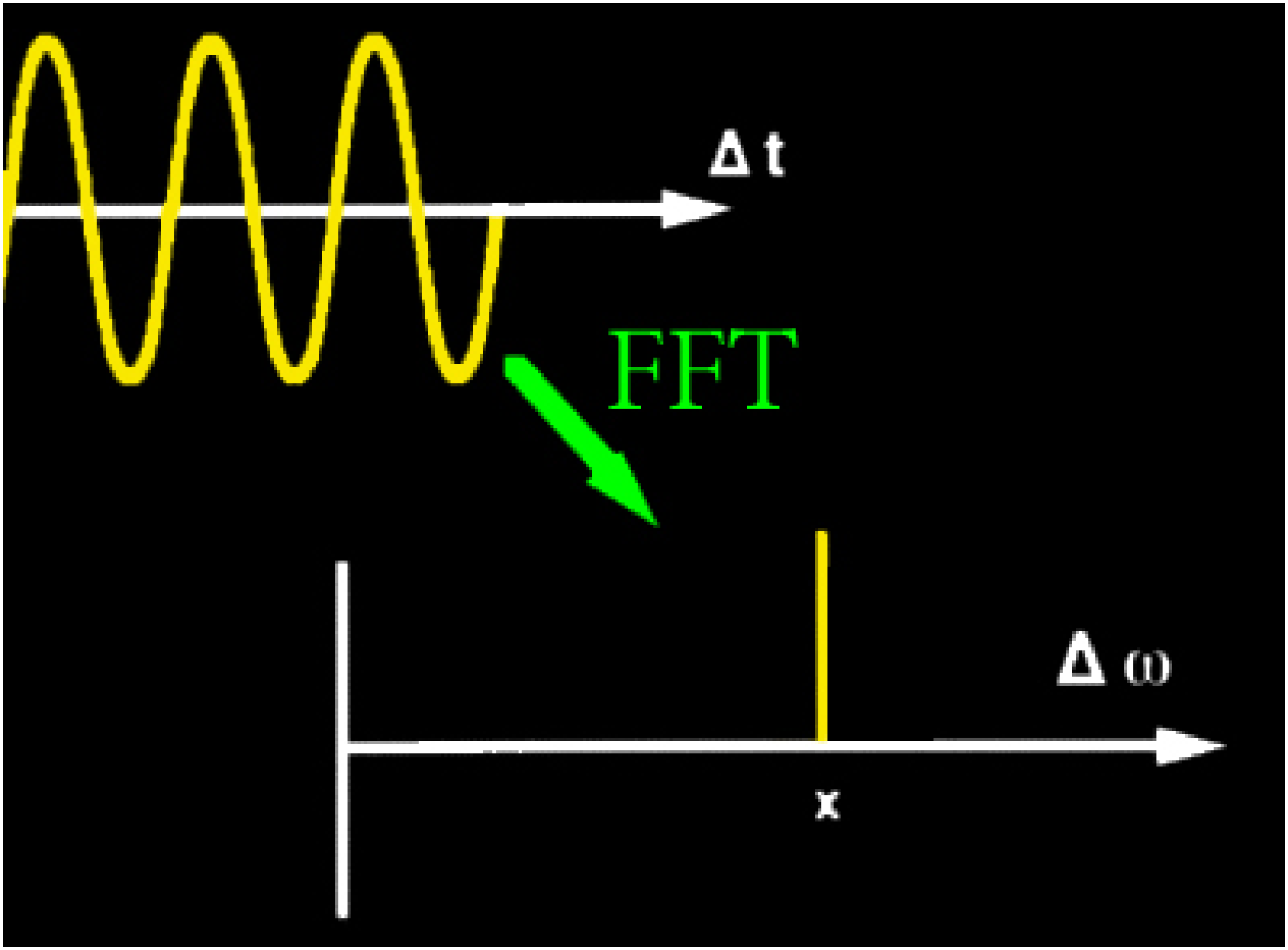
Imaging Studies

Craig *et al.* 1996



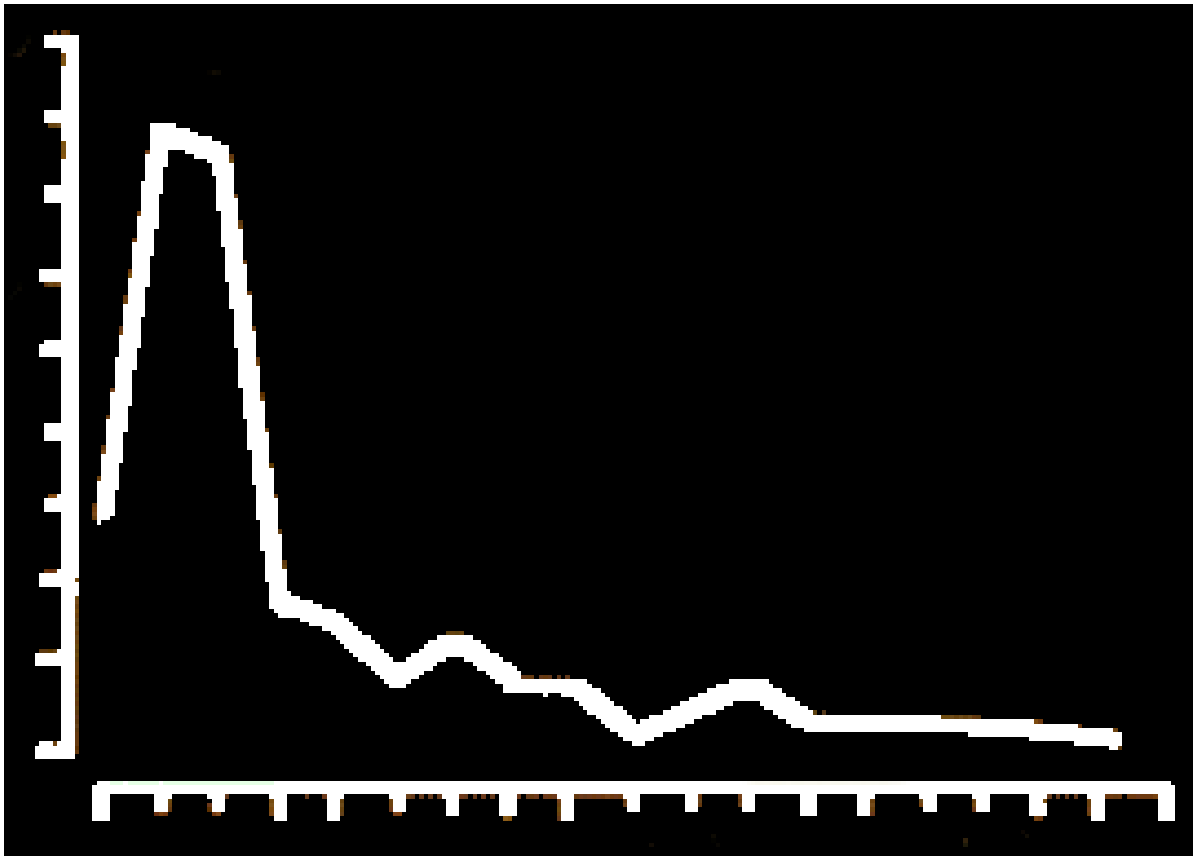
Electrophysiology




Δ t
FFT
Δ ω
x

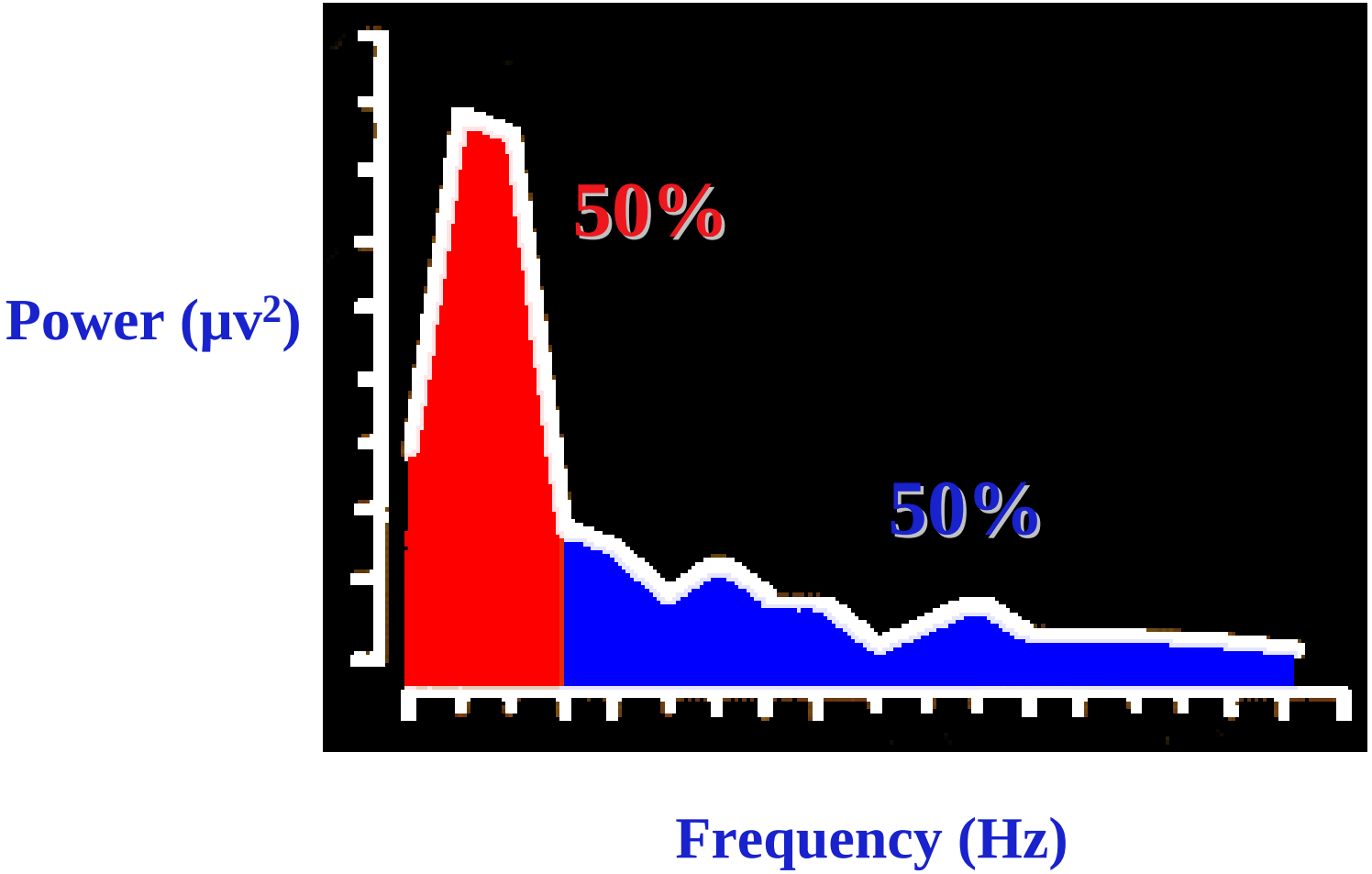
Power Spectrum

Power (μv^2)

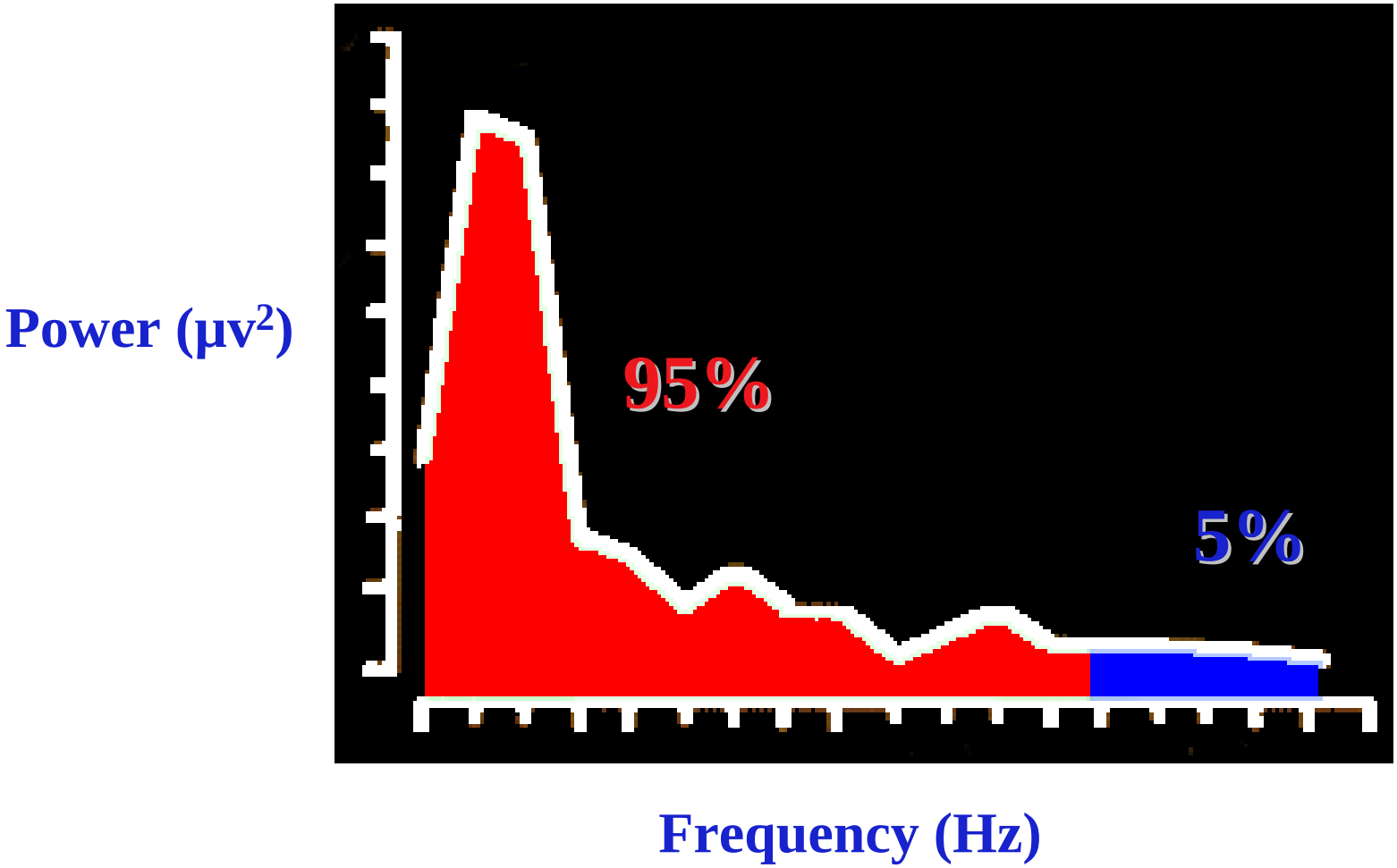


Frequency (Hz)

Median Frequency

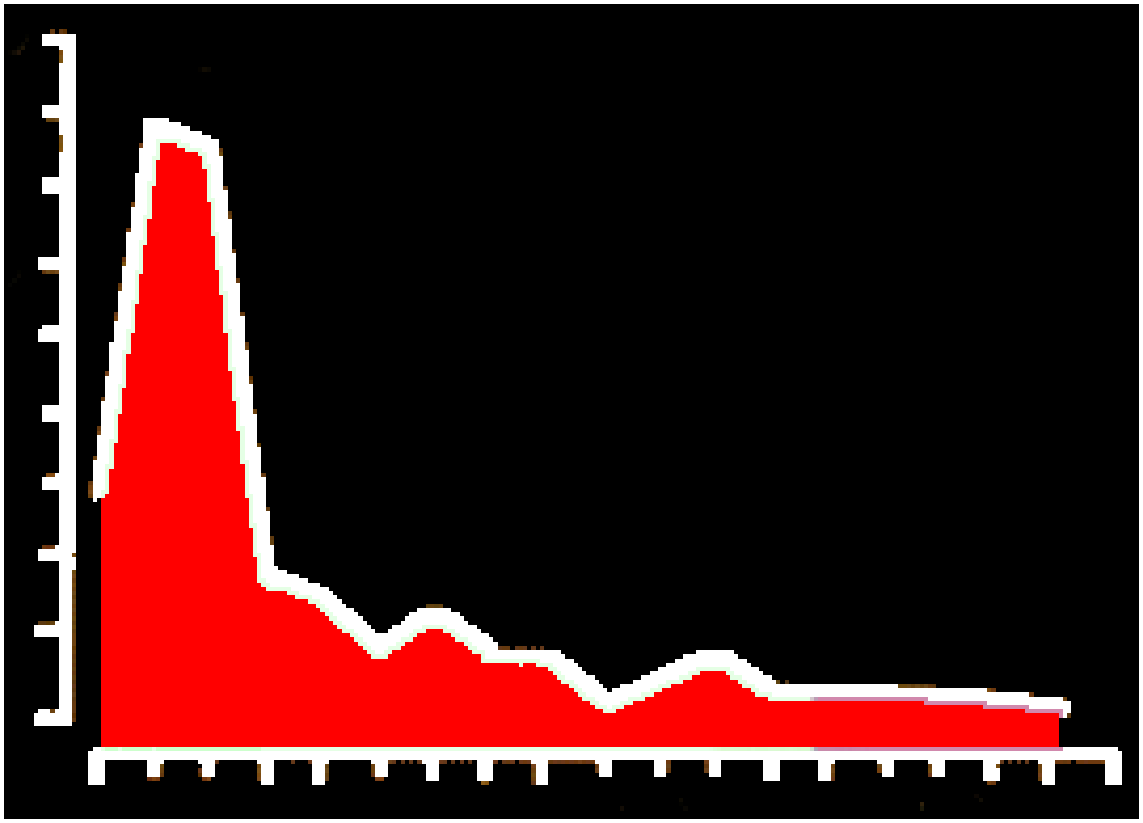


Spectral Edge Frequency (F95)

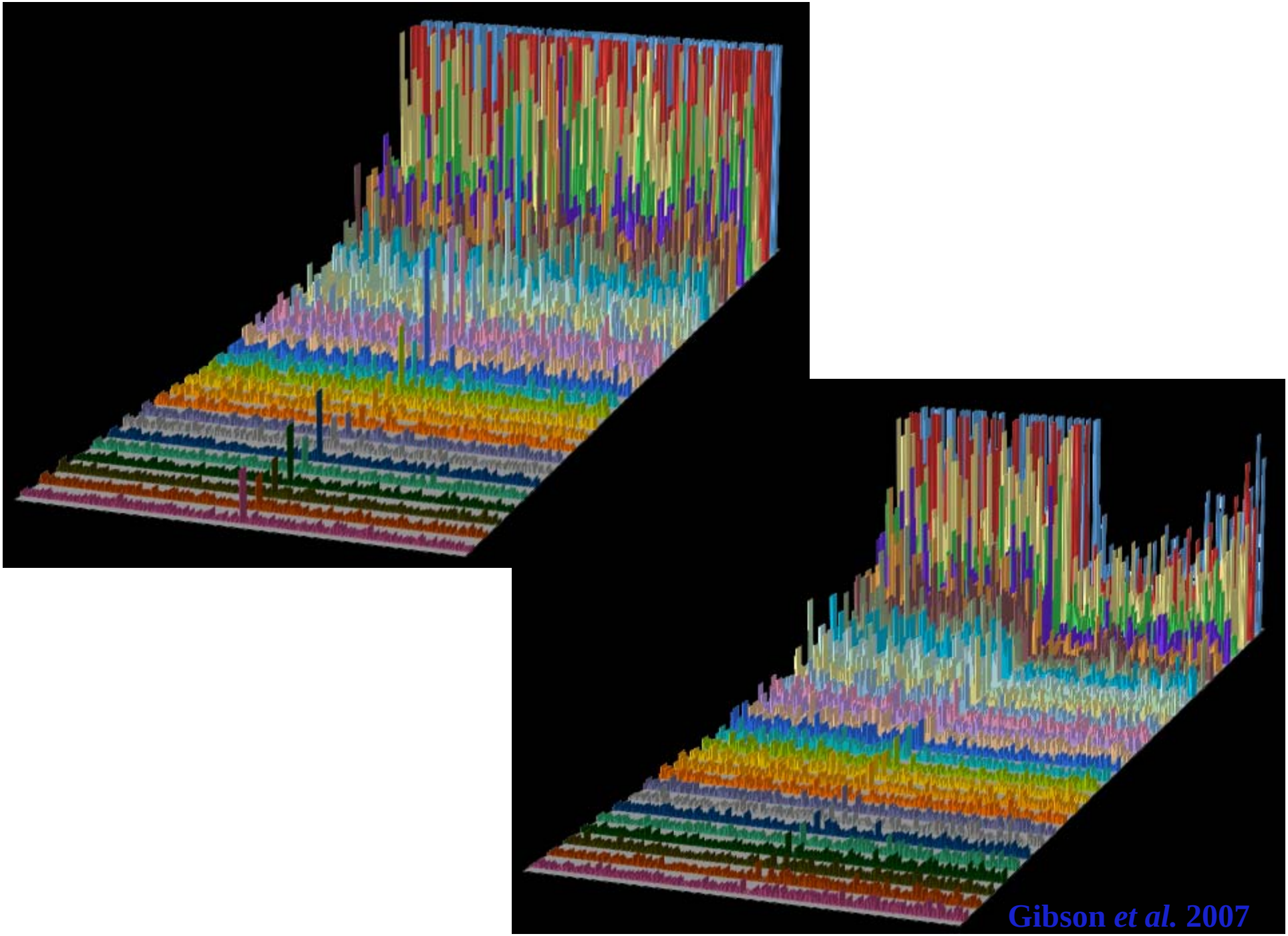


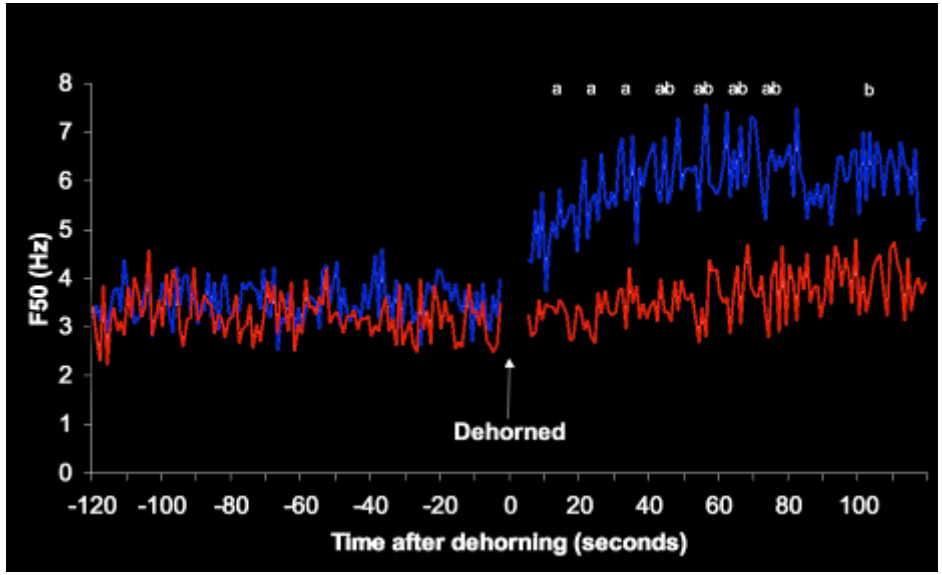
Total Power

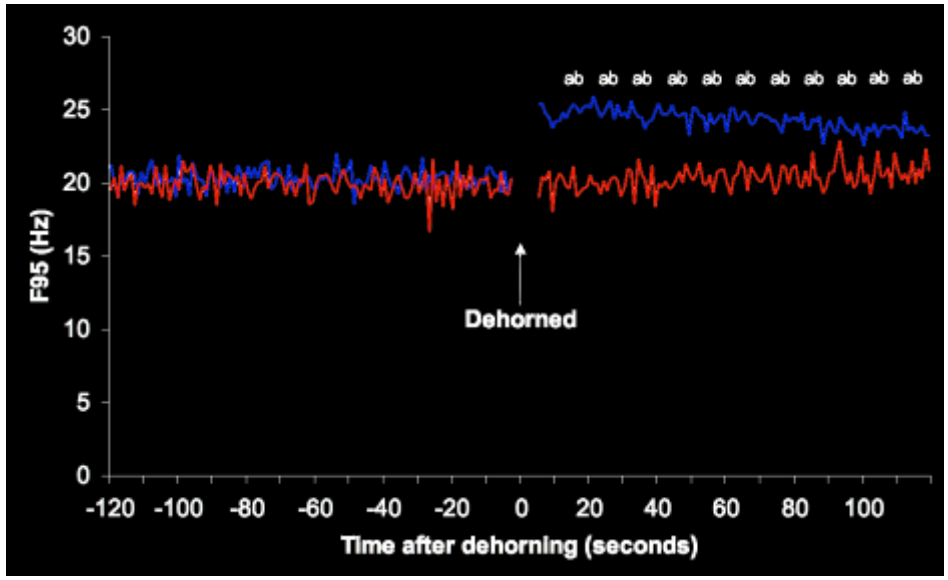
Power (μv^2)

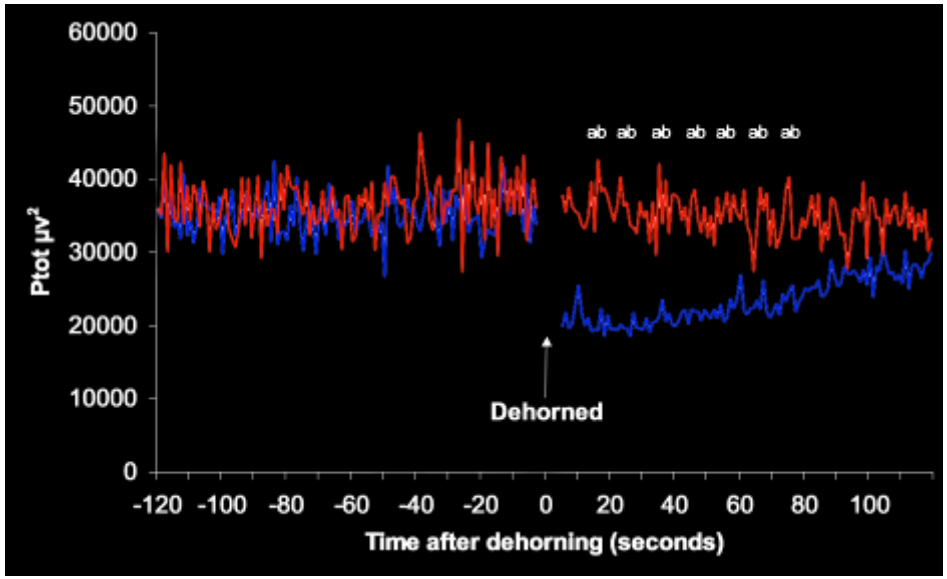


Frequency (Hz)


Gibson *et al.* 2007



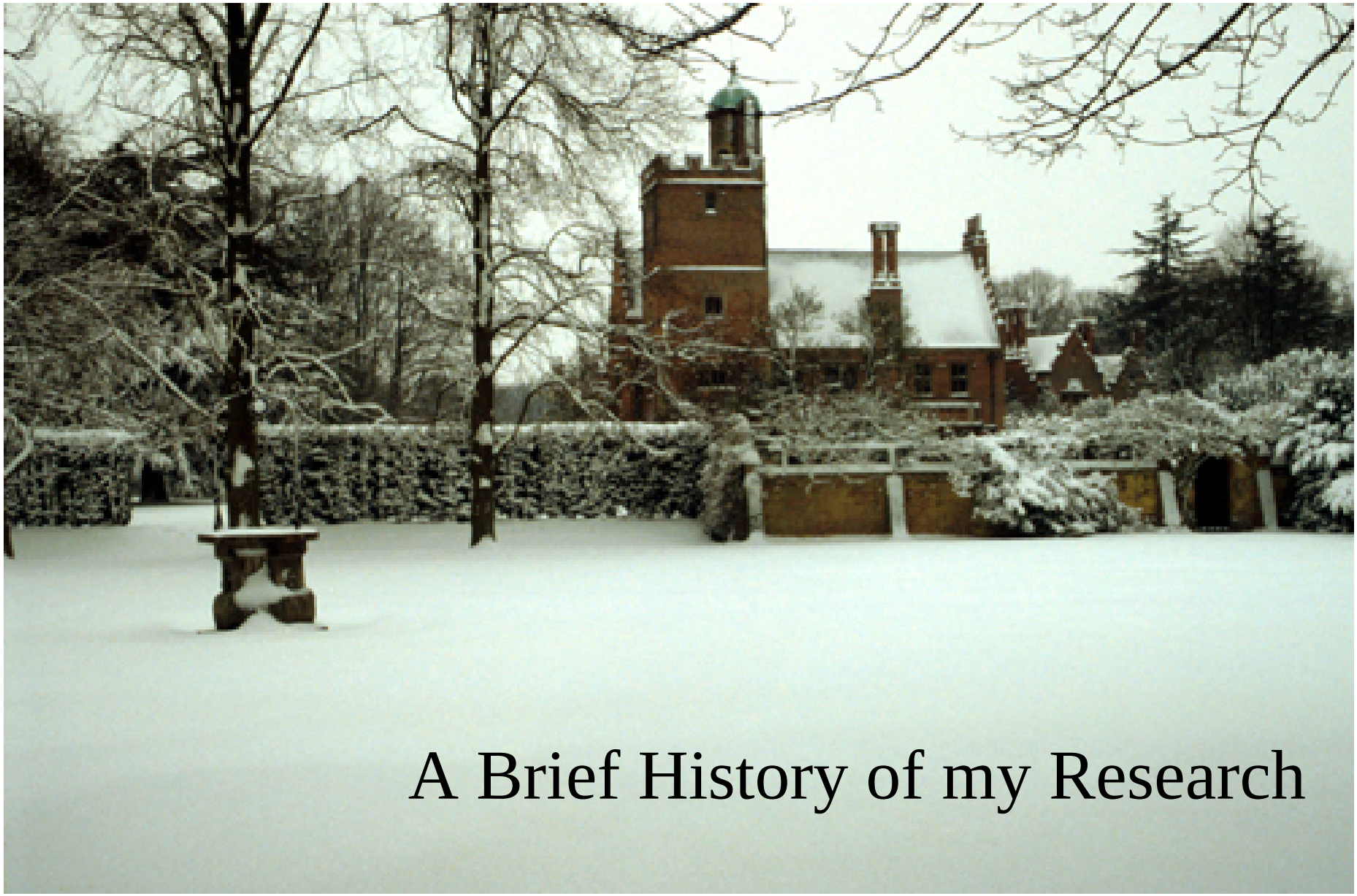




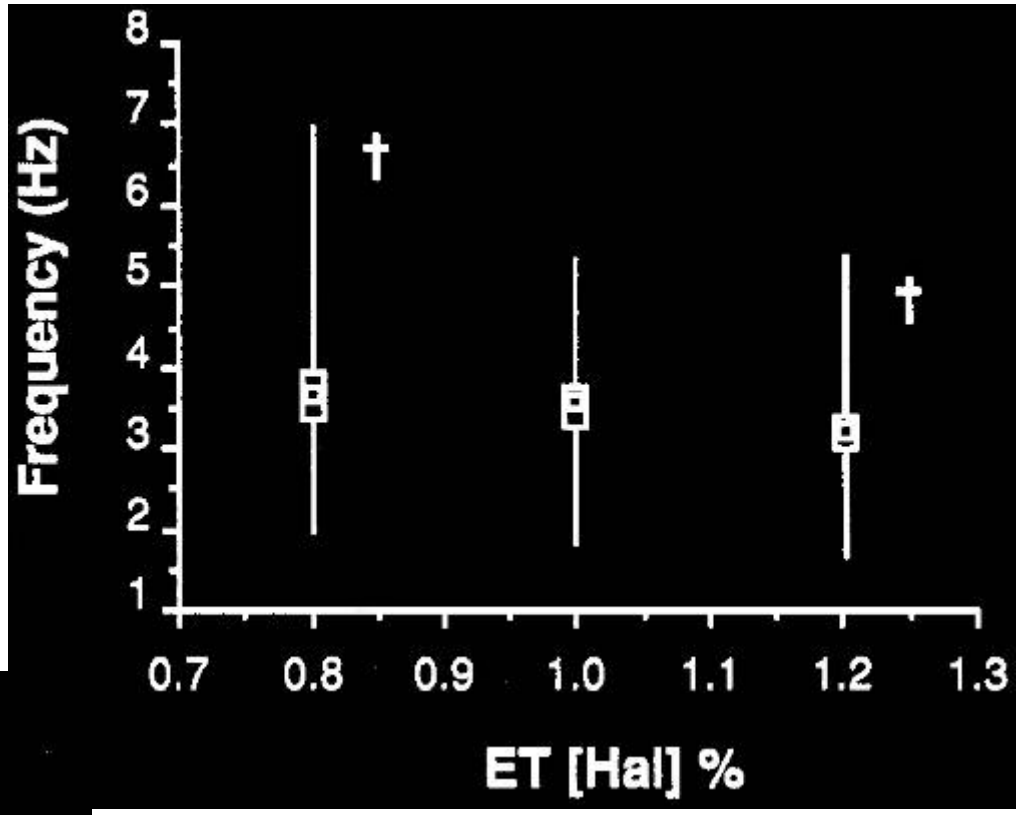
Gibson *et al.* 2007

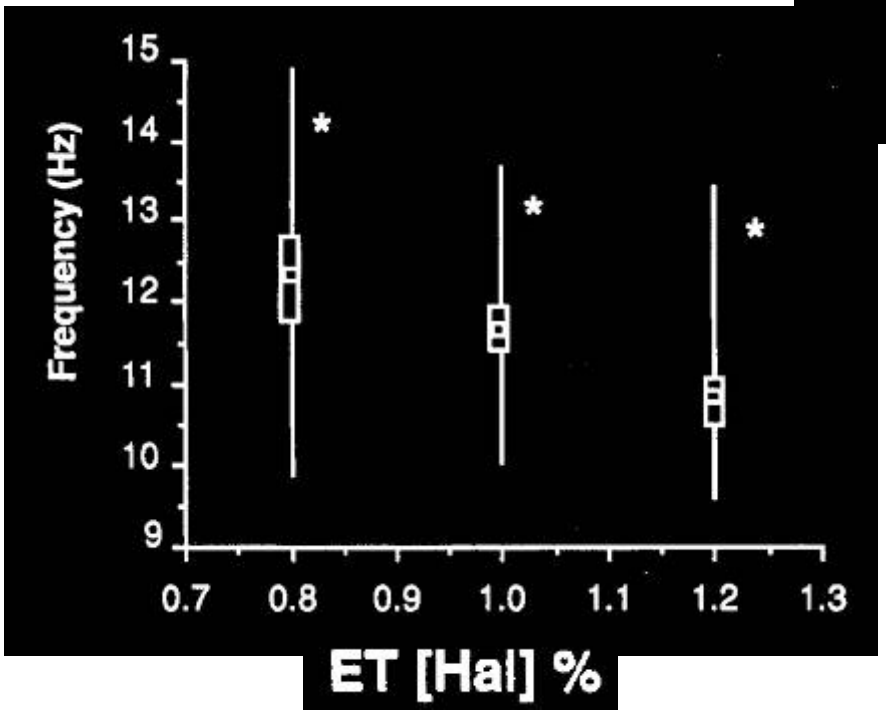
Neurophysiological techniques to assess pain in animals

JC Murrell and CB Johnson (2006)
Journal of Veterinary Pharmacology and Therapeutics **29**
325-335



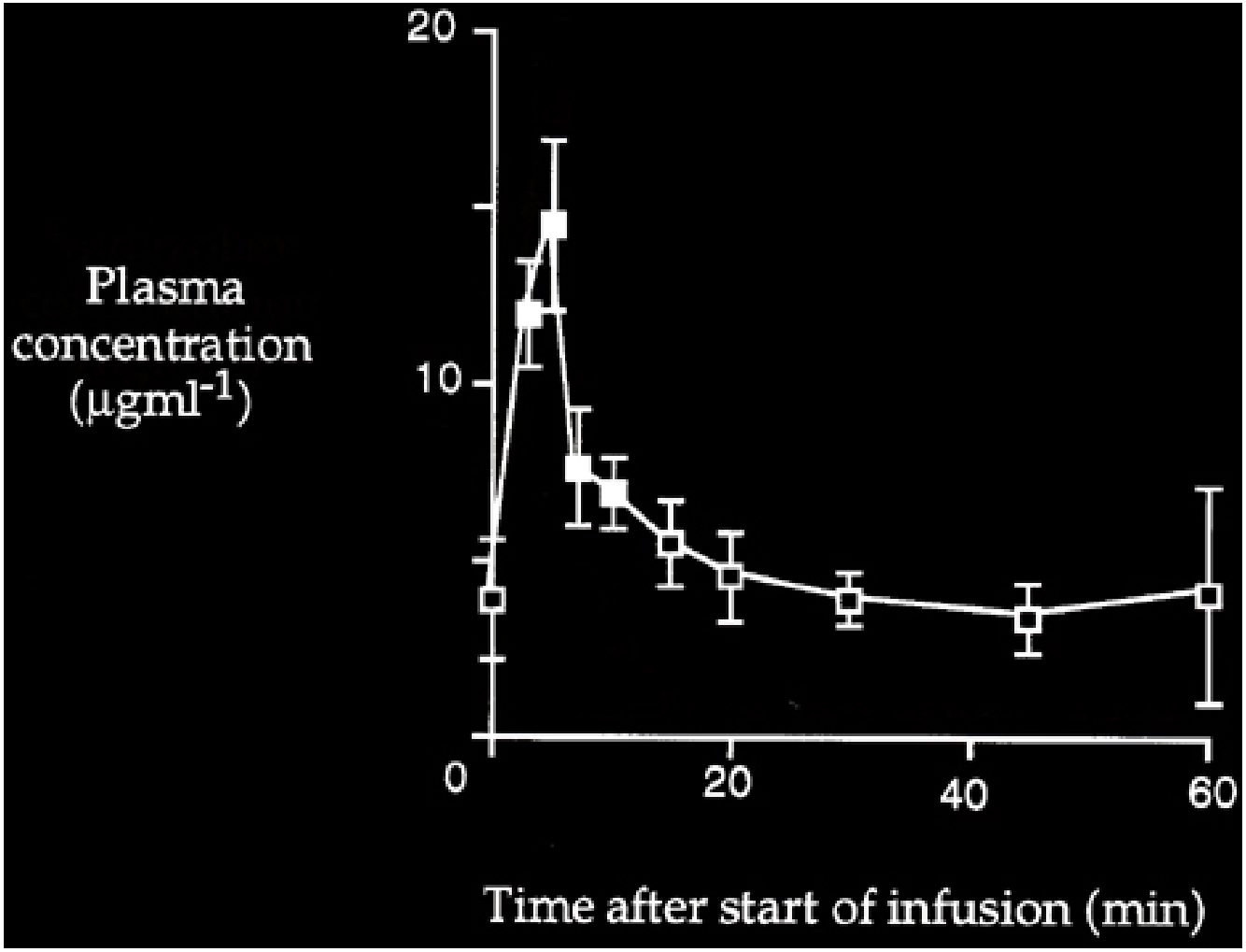
A Brief History of my Research





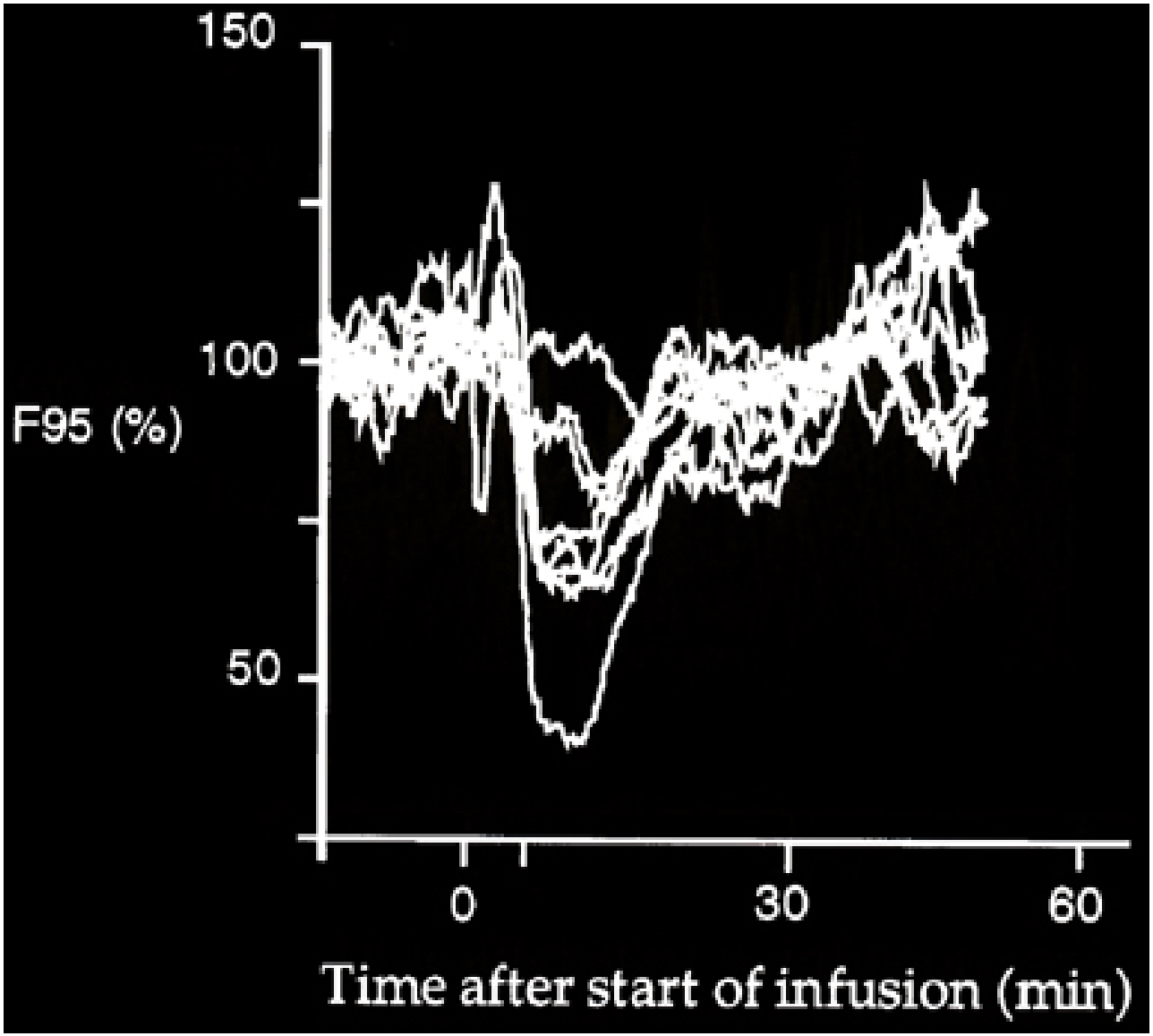
Johnson *et al.* 1994
Johnson and Taylor 1998

Infusion of Thiopentone



Johnson *et al.* 2000

Infusion of Thiopentone



Johnson *et al.* 2000

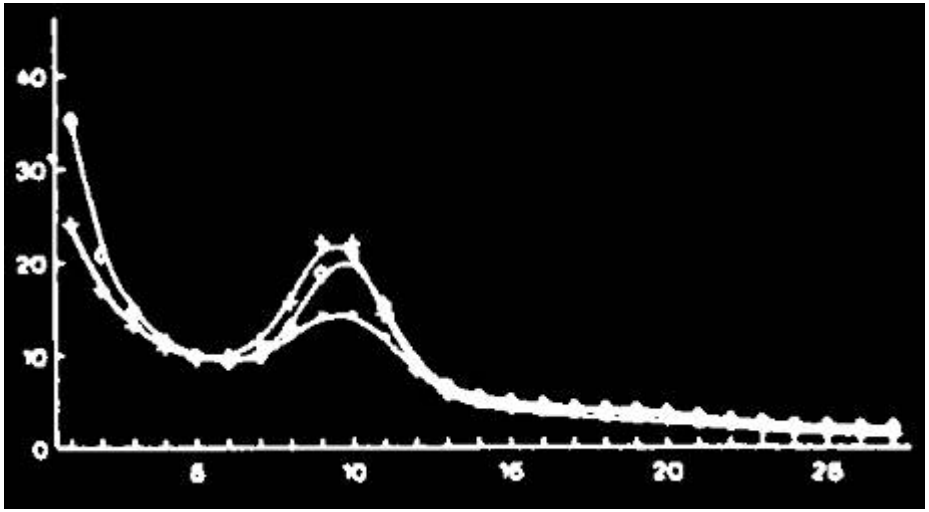
Summary of Changes in EEG Variables

	F50	F95	DD
Ketamine	↓ 31	↓ 21	↓ 23
Detomidine	↓ 13	↓ 17	↓ 24
Alfentanil	↓ 36	↓ 26	↓ 13
Thiopentone	↓ 3	↓ 27	↓ 21
Midazolam	↓ 21	↓ 40	↓ 25
GGE	↓ 8	↓ 5	↓ 14
Sarmazenil	↑ 39	↑ 56	↑ 56

P=0.05 P=0.01 P=0.001

Johnson 1996

Morris *et al.* 1997

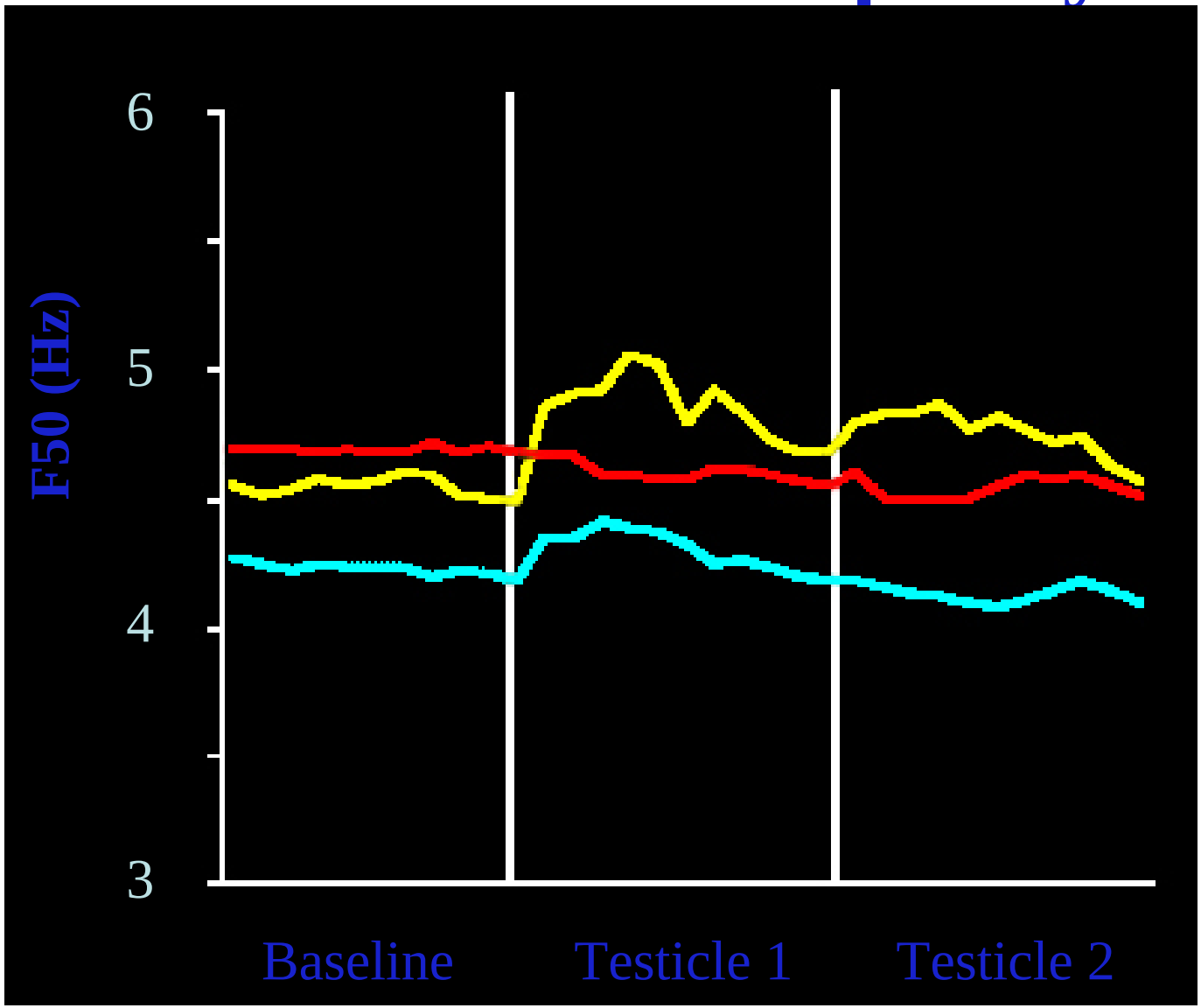


“ . . . patterned EEG activity is closely associated with human pain reactivity.”

Chen *et al.* 1989

Spontaneous EEG Changes in the Equine Surgical Patient.

Median Frequency



GTH

Alfentanil

Lidocaine

Murrell *et al.* 2003

Examples of Our Recent Research

Velvet Antler Removal
Effects of Age on Pain Perception
Slaughter in Cattle

Comparison of lidocaine and antler pedicle compression for analgesia during antler removal in red deer (*Cervus elaphus*) anaesthetised by halothane in oxygen.

C Johnson[1] M Woodbury[2] N Caulkett[2] and P Wilson[1]

[1]Te Kura Matauranga Kararehe
[2]Western College of Veterinary Medicine

Introduction

Deer farming in New Zealand is a major industry

- **Exports $257 million in 2002**

World's largest velvet antler industry

- **$36 million in 2002**
- **Traditional Chinese medicine**
- **Western health food supplement**

Velvet antler removal is a controlled surgical procedure

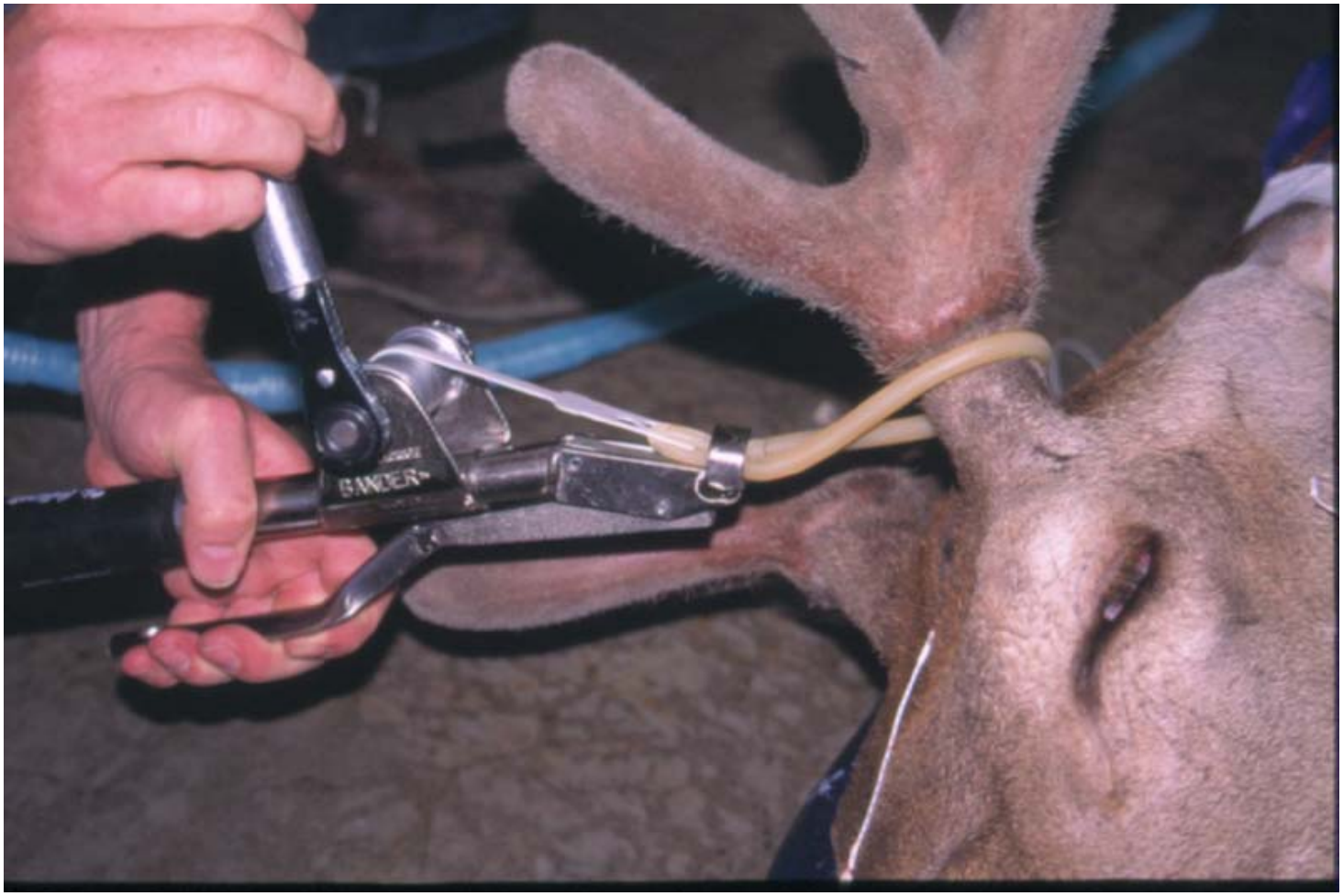
- **New Zealand Animal Welfare Act (1999)**

Most accepted method of analgesia is lidocaine ring block

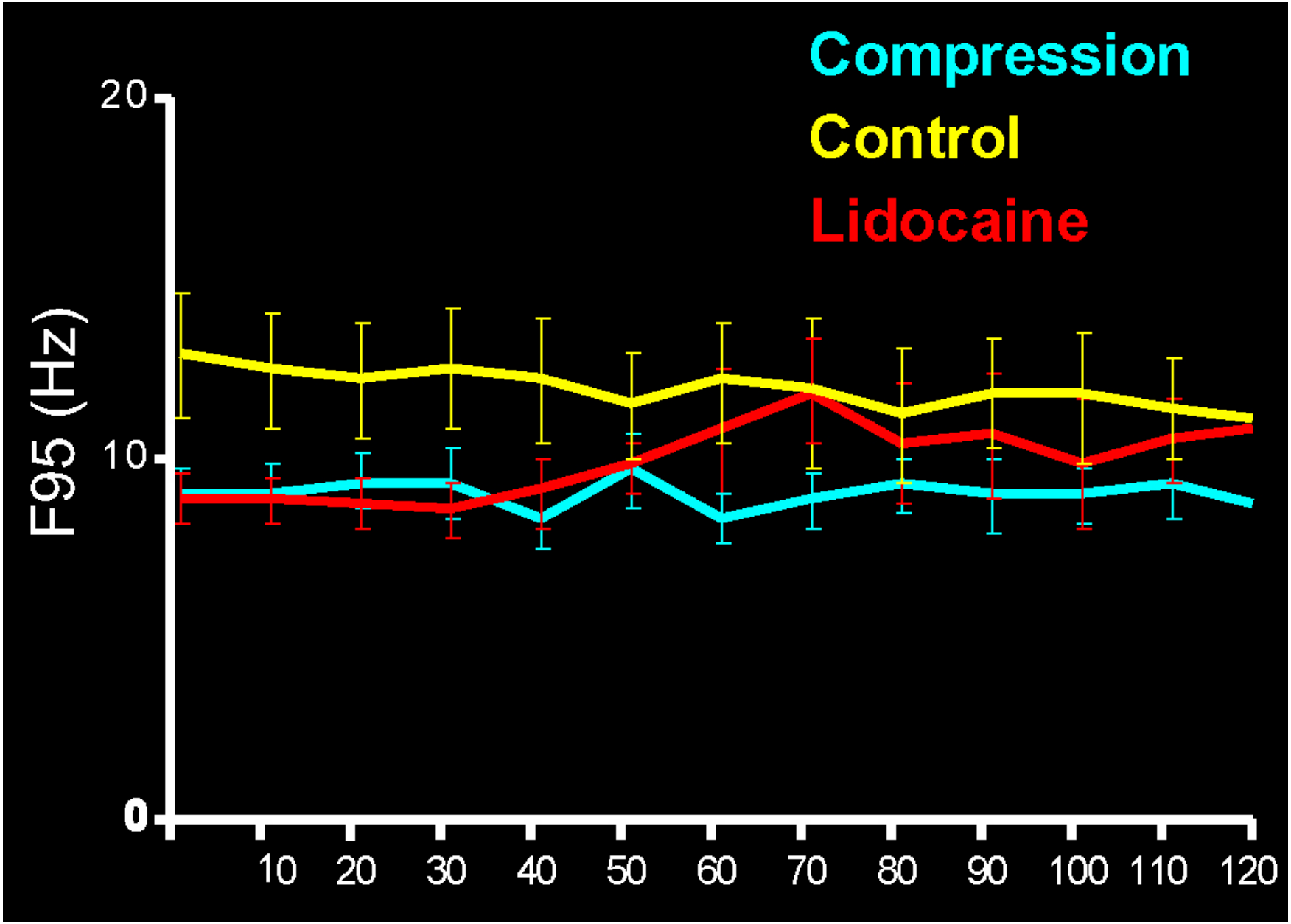
- **Risk of residues in antler**
- **Failure of technique**

Search for drug-free method of analgesia

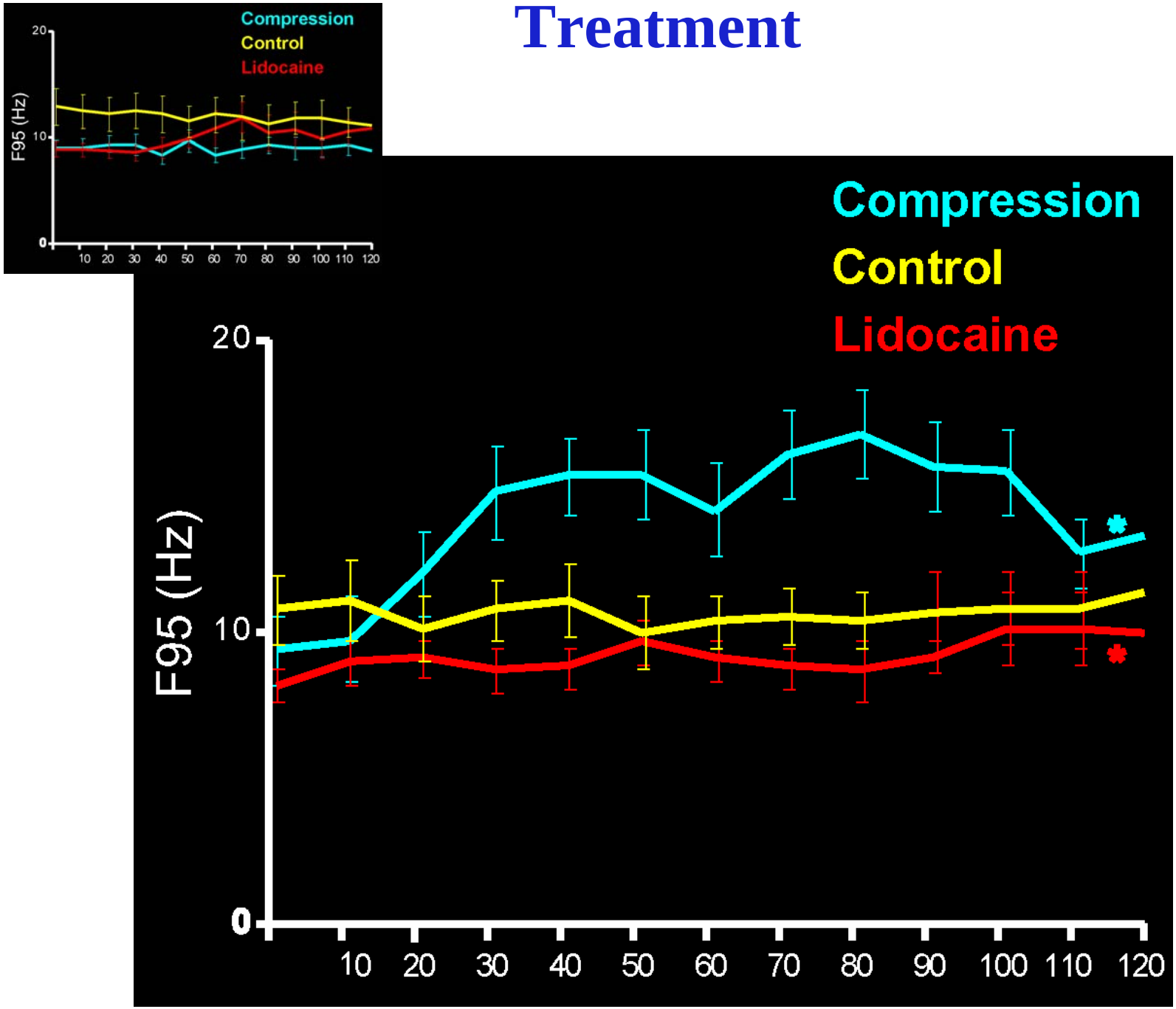
Antler Compression



Baseline


Compression
Control
Lidocaine
F95 (Hz)
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120

Treatment


Compression
Control
Lidocaine
F95 (Hz)
20
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10 20 30 40 50 60 70 80 90 100 110 120
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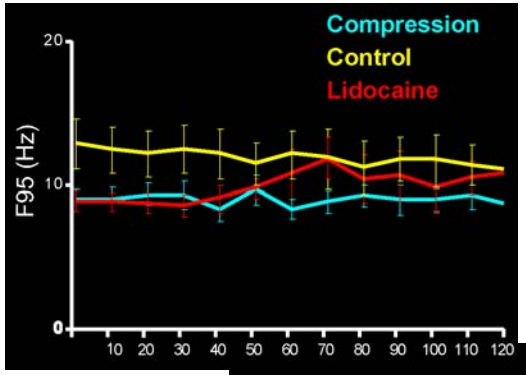
*

Removal


Compression
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Lidocaine
F95 (Hz)
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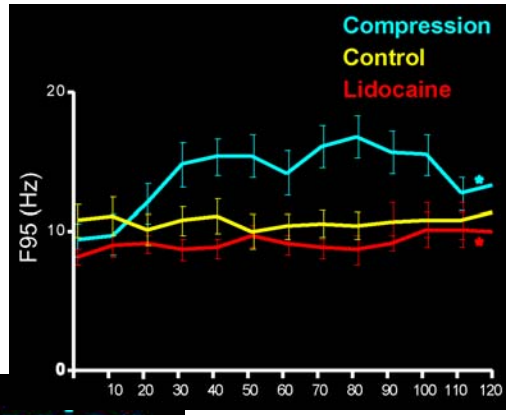
Compression
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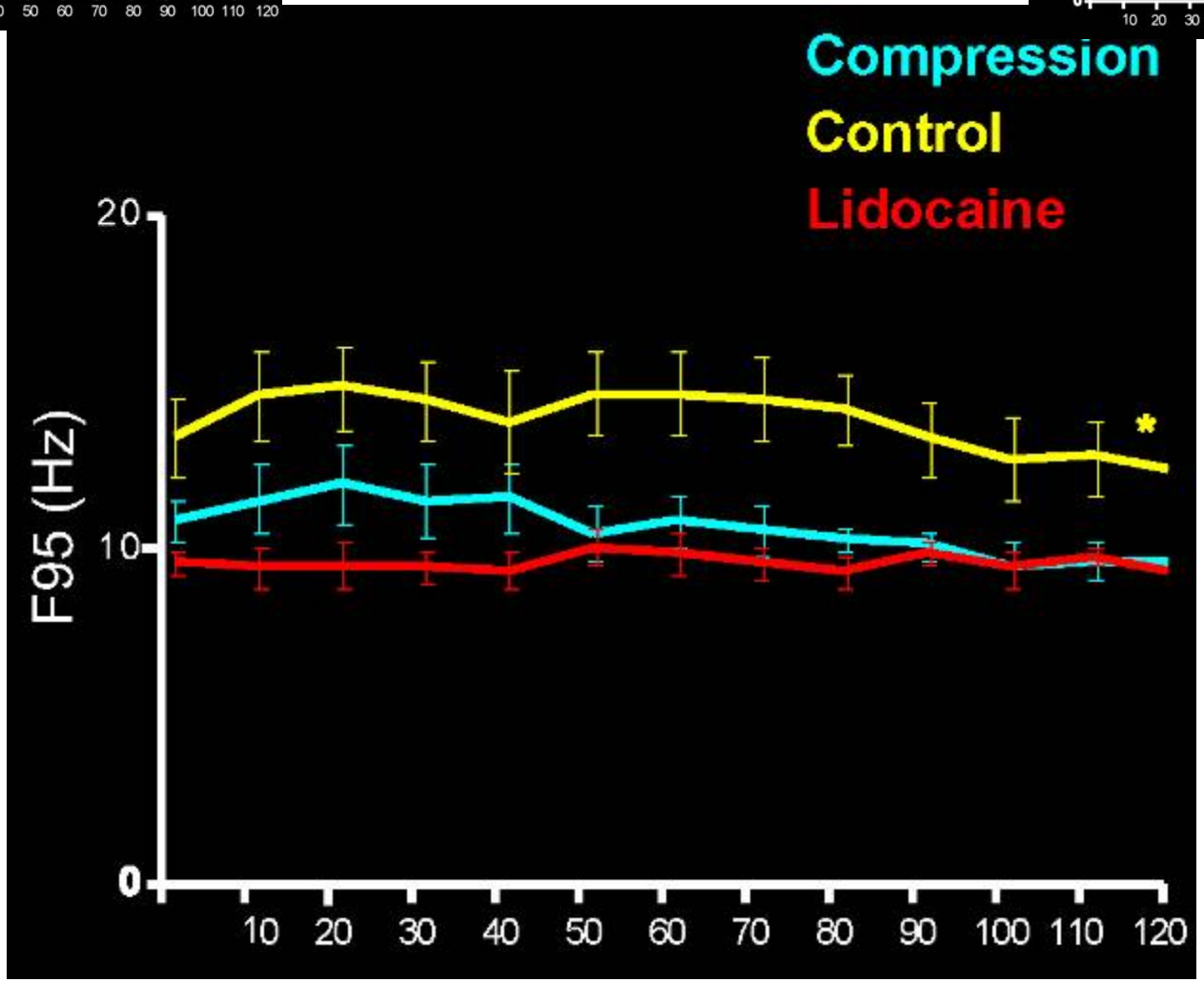

Compression
Control
Lidocaine
F95 (Hz)
20
10
0
10 20 30 40 50 60 70 80 90 100 110 120
*

Summary of Results

The control animals demonstrated EEG evidence of noxious stimulation during antler removal

The lidocaine animals did not demonstrate EEG evidence of noxious stimulation during application of ring block or subsequent antler removal

The compression group demonstrated EEG evidence of noxious stimulation during bander application and subsequent antler removal

Conclusions

Lidocaine ring block provides adequate analgesia for velvet antler removal

Application of the compression band represents a noxious stimulus in its own right

Compression is not as protective as lidocaine ring block against the noxious stimulus of surgical antler removal

Does age have any effect on perception of pain?

Cerebral Responses in Young Mammals

Precocious	Lamb
Altricial	Rat
Very Altricial	Tammar Wallaby

Tammar wallabies

Born extremely immature (~28 days GA)

Cerebral cortex at birth = 40-day human embryo

- Ear canal open	130 days
- Eyes open	140 days
- Stand unaided	160 days
- Look out of pouch	180 days
- Leave pouch	190 days

EEG responses to toe clamping in anaesthetised joeys between 95 and 260 days

Electroencephalogram

Isoelectric until ~120 days
Continuous by 140-160 days

Increase in EEG power with age

EEG response to clamp

Smaller in joeys 140-181 days
Larger in joeys 187-260 days

Results suggest that conscious perception not likely before 100-120 days present by about 160-180 days

Rat pups

Born neurologically moderately immature

- EEG differentiation into REM-non-REM sleep ~ 12-18 days

- Ear canal opening 12-13 days
- Eye opening 14 days
- Vigorous locomotor activity by 12-13 days
- Increased interest in objects by 14 days
- Play-fighting prominent by 17-20 days

EEG responses to tail clamping in anaesthetised rat pups 5-22 days after birth

Electroencephalogram + EEG response

Isoelectric - no response	5-7 days
Moderate response	12-14 days
Strong response	21-22 days

Increase in EEG power with age

Results and literature suggest:

Conscious perception not normally present before 10-12 days after birth

Rat pups older 18 days capable of conscious perception

Pups between 12-18 days might be capable of conscious perception (but what quality?)

Lambs

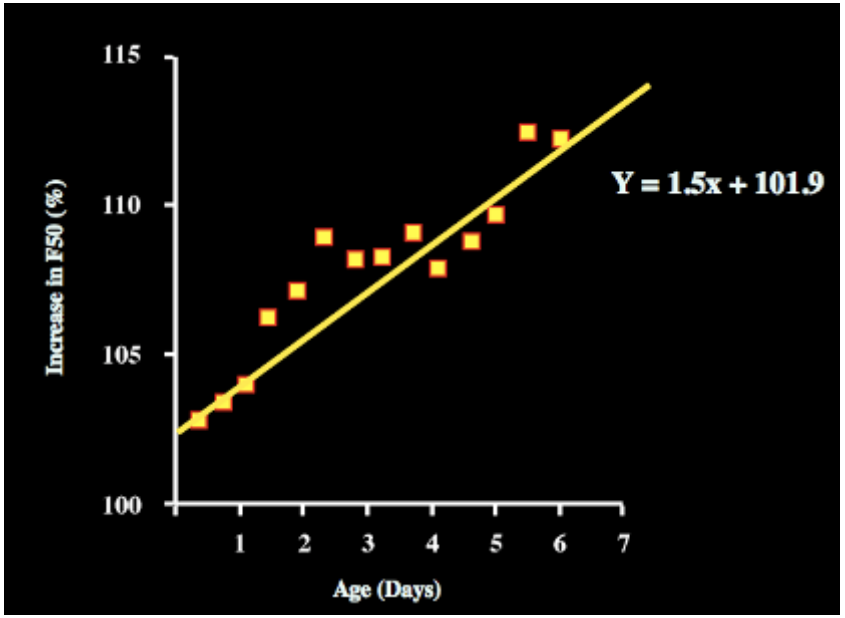
Born neurologically mature

- Ear canals open *in utero*
- Eyes open *in utero*
- REM-non-REM differentiation occurs *in utero* after 80% of gestation.

Conscious perception soon after birth

- lambs' volitional responses to maternal and environmen stimulation
- sleep-wake cycles well established within a day or so after birth

EEG responses to castration in anaesthetised lambs from 3hrs to 36 days after birth



Johnson et al. (In Press)

Conscious Perception and Suffering may not occur until some time after birth even in precocious mammals

Conscious Perception and Suffering may not occur until some time after birth even in precocious mammals

BUT

Negative Effects of Pain

Perception

Cerebral Cortex

Johnson and Murrell
Haga
Chen

Hyperalgesia

Spinal Cord (and other locations)

Waterman
Taddio
Grunau

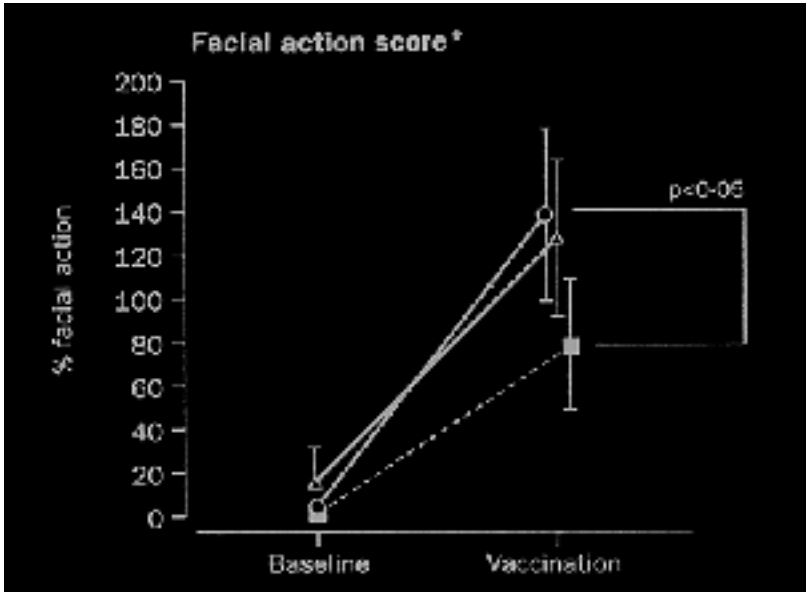
Table 3. Measures of Tenderness in Preterm and Full-Term Children by Sex

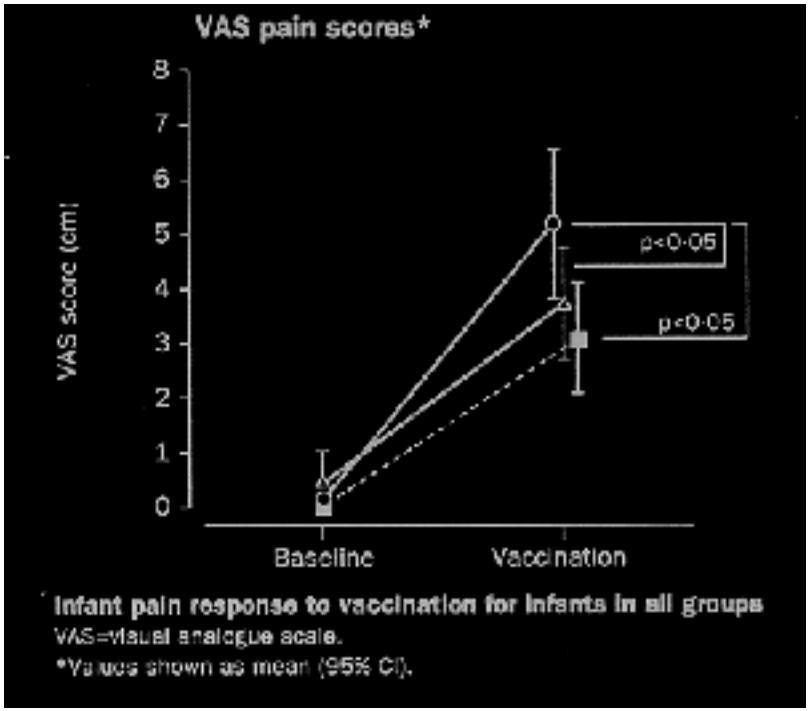
Measure (Range)	Mean (SD)				*P* Value	
	Preterm		Full-Term			
	Boys (n = 24)	Girls (n = 36)	Boys (n = 27)	Girls (n = 33)	Group	Sex
No. of tender points (1-18)	4.8 (4.8)	6.8 (5.4)	2.7 (2.3)	4.0 (3.8)	.003	.04
Dolorimetry threshold, kg (range, 0-9)						
Mean at 9 tender points	5.0 (1.7)	3.7 (1.2)	5.5 (1.7)	4.2 (1.4)	.07	.001
Mean at 4 control points	7.2 (1.7)	5.7 (1.7)	7.5 (1.5)	6.5 (1.4)	.049	.001

This study demonstrates increased tenderness at tender point sites in prematurely born adolescents compared with full-term children. This is the most comprehensive controlled study in this age group, using quantitative assessment of pain thresholds.

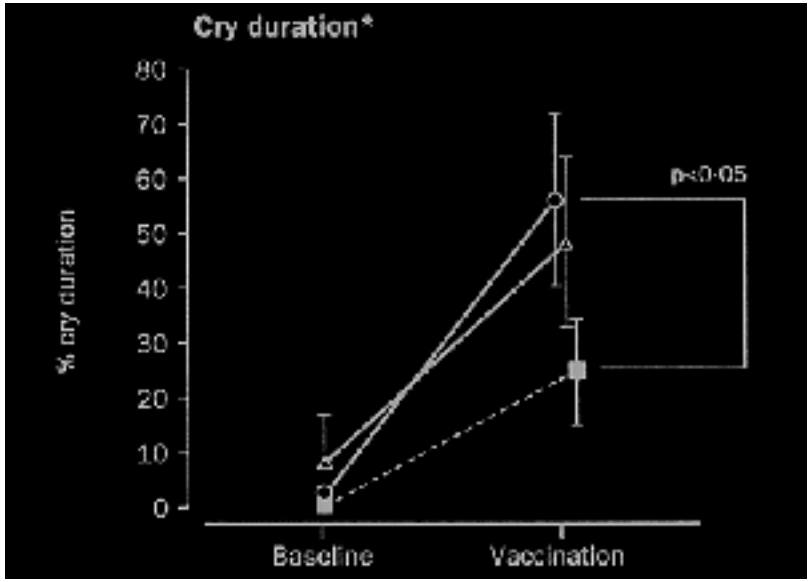
Buskila et al. (2003)

Effect of neonatal circumcision on pain response during subsequent routine vaccination



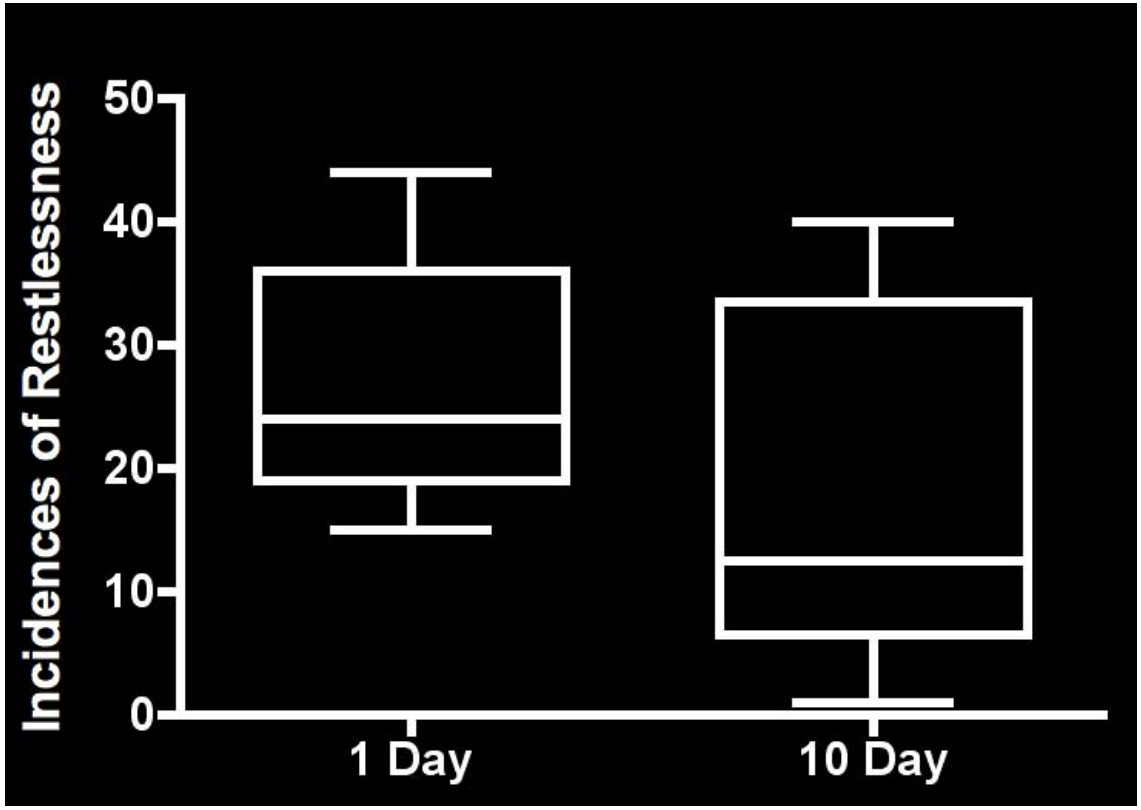


Infant pain response to vaccination for infants in all groups
VAS=visual analogue scale.
*Values shown as mean (95% CI).



Taddio et al. (1997)

Does age of Castration Influence Post-Castration Hyperalgesia in Lambs?



McCracken et al. (2006)

Castration at one day of age appears to cause more hyperalgesia than castration at ten days of age

This may reflect absence of descending inhibition in very young animals


6 Medium British eggs
eggs from caged hens
69p

An Investigation into the Effects of Slaughter by Ventral Neck Incision in Calves

TJ Gibson, CB Johnson, DJ Mellor and KJ Stafford

defra
Department for Environment Food and Rural Affairs

MAF BIOSECURITY NEW ZEALAND

Massey University

Massey University Comparative Analgesia Group
"Team Ouch"

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Kavitha Konagara; Troy Gibson; Vikki Walsh;
Pania Flint; Leanne McCracken; Paul Battersby;
Des Waters; Megan McGregor; Amanda McIlhone.