The Role of Electroencephalography in Animal Welfare Research

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

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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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
Where Are The Limits of Pain?
Where Are The Limits of Pain?
Imaging Studies

Craig et al. 1996

Anterior cingulate

Insula

Noxious Cold

Cool

Warm

Noxious Heat
Electrophysiology
Power Spectrum

Power ($\mu v^2$)

Frequency (Hz)
Median Frequency

Frequency (Hz)

Power ($\mu$V$^2$)

50% 50%
Spectral Edge Frequency (F95)

Power (µv²)

Frequency (Hz)
Total Power

Power (µv²)

Frequency (Hz)
Neurophysiological techniques to assess pain in animals

A Brief History of my Research
Infusion of Thiopentone

Plasma concentration (μgml⁻¹)

Time after start of infusion (min)

Johnson et al. 2000
Infusion of Thiopentone

Johnson et al. 2000
### Summary of Changes in EEG Variables

<table>
<thead>
<tr>
<th></th>
<th>F50</th>
<th>F95</th>
<th>DD</th>
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</thead>
<tbody>
<tr>
<td>Ketamine</td>
<td>↓31</td>
<td>↓21</td>
<td>↓23</td>
</tr>
<tr>
<td>Detomidine</td>
<td>↓13</td>
<td>↓17</td>
<td>↓24</td>
</tr>
<tr>
<td>Alfentanil</td>
<td>↓36</td>
<td>↓26</td>
<td>↓13</td>
</tr>
<tr>
<td>Thiopentone</td>
<td>↓3</td>
<td>↓27</td>
<td>↓21</td>
</tr>
<tr>
<td>Midazolam</td>
<td>↓21</td>
<td>↓40</td>
<td>↓25</td>
</tr>
<tr>
<td>GGE</td>
<td>↓8</td>
<td>↓5</td>
<td>↓14</td>
</tr>
<tr>
<td>Sarmazenil</td>
<td>↑39</td>
<td>↑56</td>
<td>↑56</td>
</tr>
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P=0.05 | P=0.01 | P=0.001

Johnson 1996
“... patterned EEG activity is closely associated with human pain reactivity.”

Chen et al. 1989
Spontaneous EEG Changes in the Equine Surgical Patient.
Median Frequency

![Graph showing frequency changes with labels for GTH, Alfentanil, and Lidocaine.](image)

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\textsuperscript{1} M Woodbury\textsuperscript{2} N Caulkett\textsuperscript{2} and P Wilson\textsuperscript{1}

\textsuperscript{1}Te Kura Matauranga Kararehe
\textsuperscript{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
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
Treatment
Removal
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
Altricial
Very Altricial
Lamb
Rat
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 environmental 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
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

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

TJ Gibson, CB Johnson, DJ Mellor and KJ Stafford
Massey University Comparative Analgesia Group
“Team Ouch”

Faculty:
Craig Johnson; Paul Chambers; Ngaio Beausoleil.

Postdoctoral Fellow:
Jo Murrell.

Technicians:
Sheryl Mitchinson; Neil Ward; Mike Giesig;
Shauna Sylvester.

Research Students:
Nacho Lizarraga; Tamara Diesch;
Kavitha Konagara; Troy Gibson; Vikki Walsh;
Pania Flint; Leanne McCracken; Paul Battersby;
Des Waters; Megan McGregor; Amanda McIlhone.