Effects of varying linear acceleration on the vestibular-evoked myogenic potential (VEMP)

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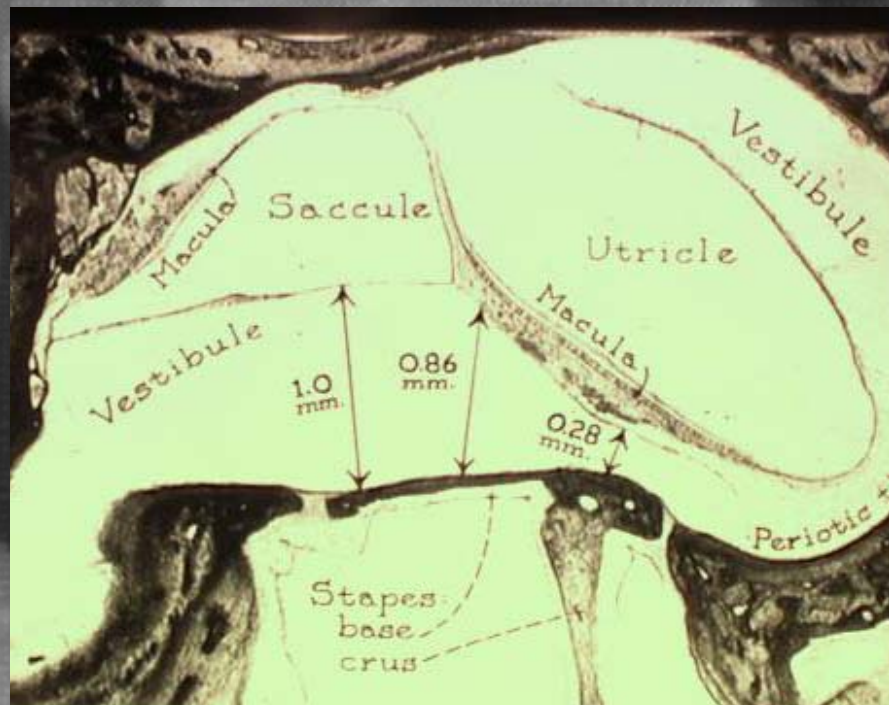
LRY: "We need to study the saccule"

Evidence for saccular source of VEMP

- Vestibular afferents respond to high intensity sound stimulation
  - Saccular afferents in squirrel monkey (Young, et al., 1977)
  - Primary afferents from saccule in cat (McCue and Guinan 1994)
  - located mainly in macular region (McCue and Guinan, Jr. 1997).
  - Click sensitive neurons in guinea pig vestibular nerve respond to tilt (Murofushi, et al., 1995; Murofushi and Curthoys 1997)

- Saccule is close to the stapes footplate

- Bullfrog saccule is a seismic sensor, responding to vibration even in the presence of 1g (Eatock, et al., 1987)



VEMP putative pathway

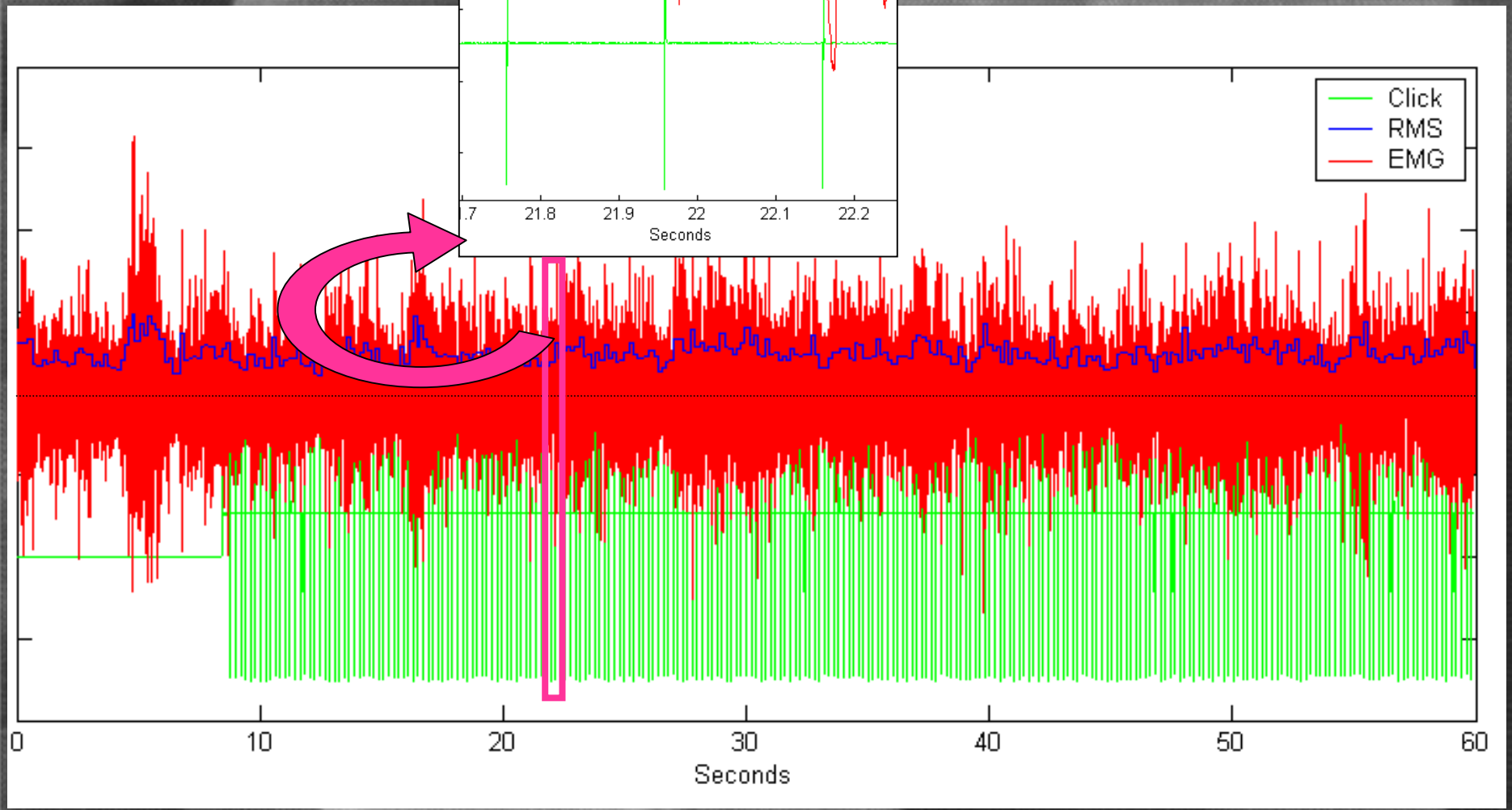
•Saccular afferents have disynaptic inhibitory input to the ipsilateral neck flexor motor neurons, projecting via the medial vestibular spinal (MVST) or reticulospinal tracts, with IPSP latencies of 1.7 – 3.6 msec

•Ipsilateral inputs were found to be two times stronger than contralateral projections, consistent with the findings of ipsilateral responses to click stimuli in the VEMP (Uchino et al., 1997)

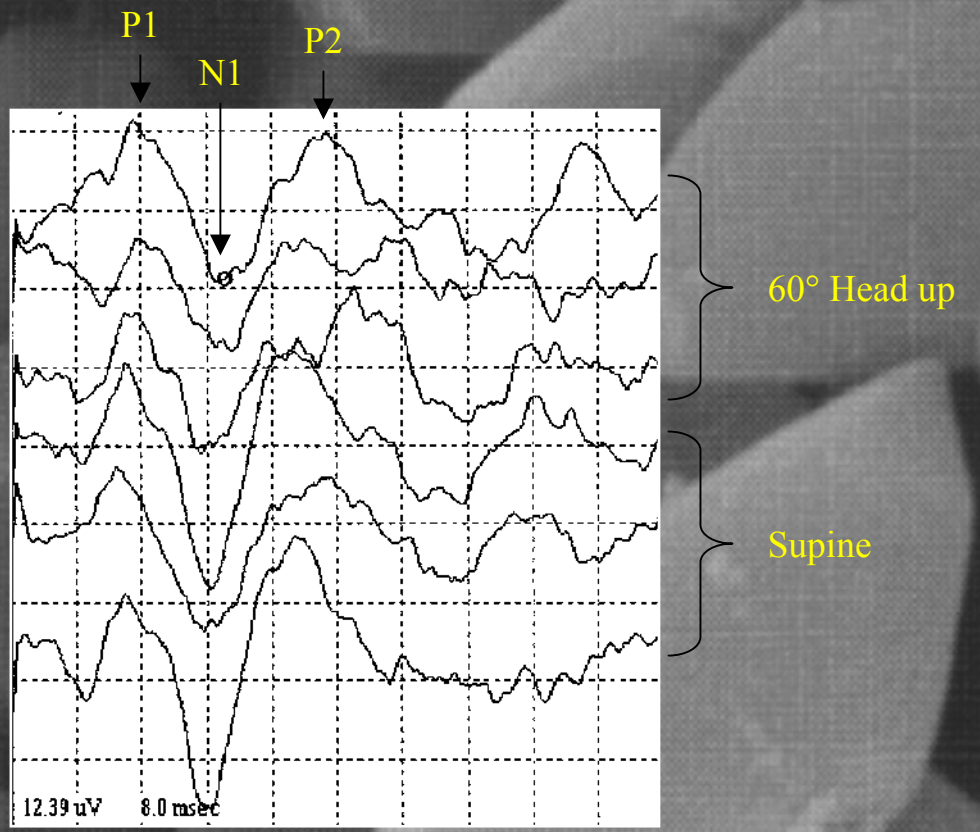
Diversity of methodology

Title	Authors	Orientation	Flexing
VEMP in Humans: a Review	Viart, Dubreuil, Duclaux	?	?
Myogenic potentials generated by a click-evoked vestibulocollic reflex	Colebatch, Halmagyi, Skuse	upright (seated)	Forward
Clinical and Electrophysiological Findings in the Tullio Phenomenon	Bronstein, Faldon, Rothwell, Gresty, Colebatch, Ludman	upright (seated)	Forward (referenced 2)
Vestibular-evoked electromyographic responses in soleus: a comparison between click and galvanic stimulation	Watson, Colebatch	"standing & leaning slightly forward"	Turned
Vestibular Evoked Myogenic Potentials	Robertson, Ireland	Supine	Forward
Responses of guinea pig primary vestibular neurons to clicks	Murofushi, Curthoys, Topple, James Colebatch, Halmagyi	N/A	N/A
Click evoked myogenic potentials in the differential diagnosis of acute vertigo	Freitag, Wollenberg, Iro, Schimrigk, Dillmann	Supine	Forward
The Influence of Voluntary EMG Activity and Click Intensity on the Vestibular Click Evoked Myogenic Potential	Lim, Clouston, Sheean, Yiannikas	?	?
Vestibular hypersensitivity to clicks is characteristic of the Tullio Phenomenon	Colebatch, Day, Bronstein, Davies, Gresty, Luxon, Rothwell	upright (seated)	Forward
Characteristics of Tone Burst-evoked Myogenic Potentials in the Sternocleidomastoid Muscles	Welgampola, Colebatch	Supine ("recumbant")	Forward
Short tone burst-evoked myogenic potentials on the sternocleidomastoid muscle. Are they also of vestibular origin?	Murofushi, Matsuzaki, Wu	Supine	Turned
Vestibular evoked potentials in human neck muscles before and after unilateral vestibular deafferentation	Colebatch, Halmagyi	?	?
Click-evoked vestibular activation in the Tullio Phenomenon	Colebatch, Rothwell, Bronstein, Ludman	upright (seated)	"activate her neck flexors tonically"

Example of raw data



Method



95 dB clicks, .1 msec duration, 5.1 Hz

EarTone 3A Transducer

EMG from ipsilateral sternocleidomastoid muscle, sampled at 4 kHz

Feedback of RMS EMG provided to subject

Average of 200 clicks

Analysis

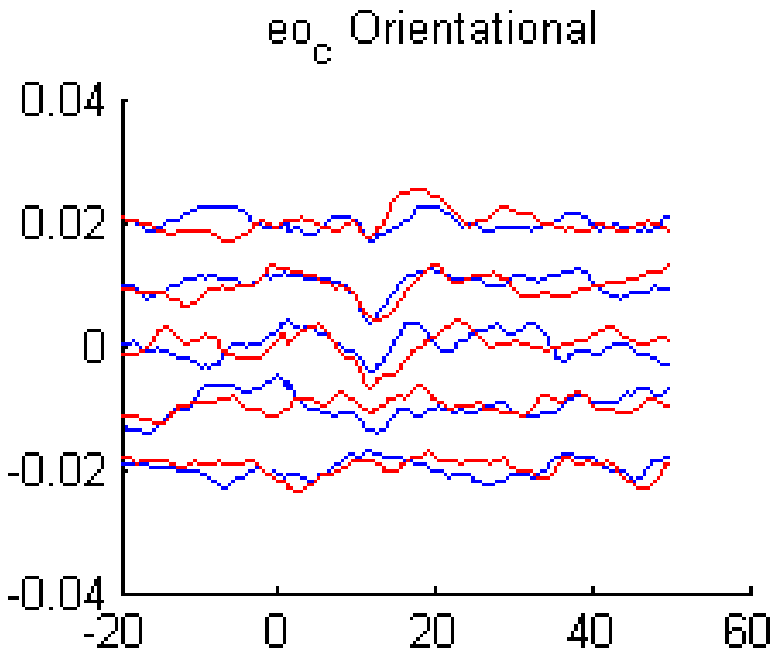
•Click intensity and background EMG activity in SCM affect VEMP amplitude.

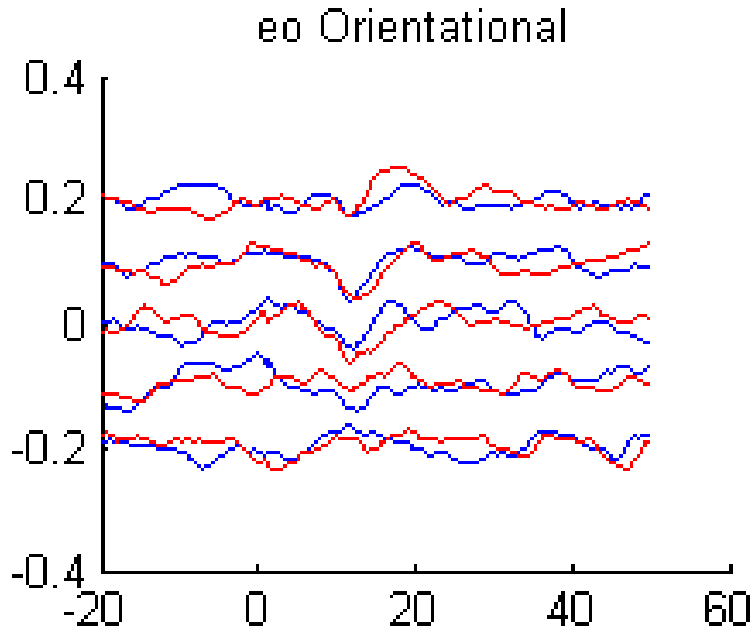
•A relationship between these parameters and the magnitude of the VEMP was determined (Lim et al, 1995)

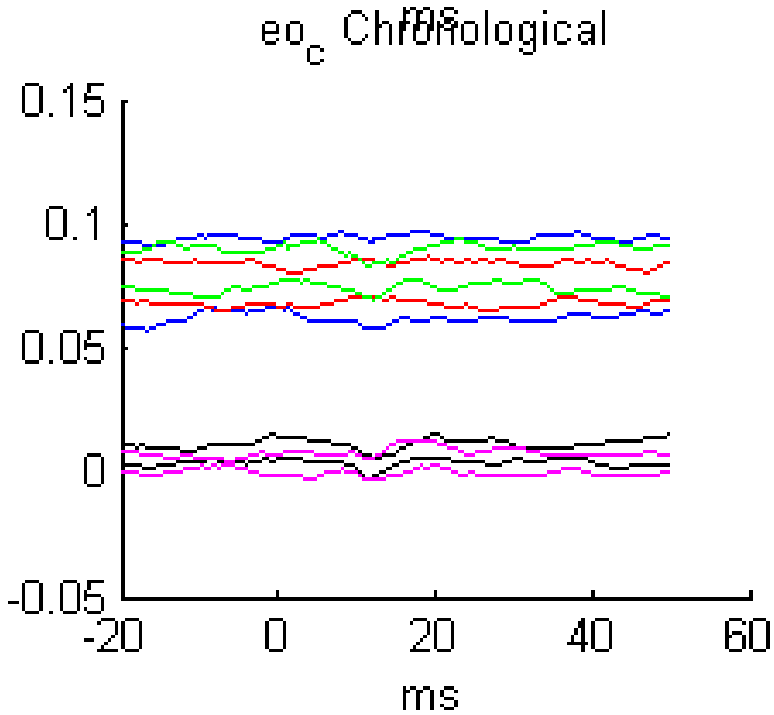
P1/N1 amp = 8.2*(click intensity) + .4*(EMG RMS) – 715
correlation = 0.7
$p<.0001$

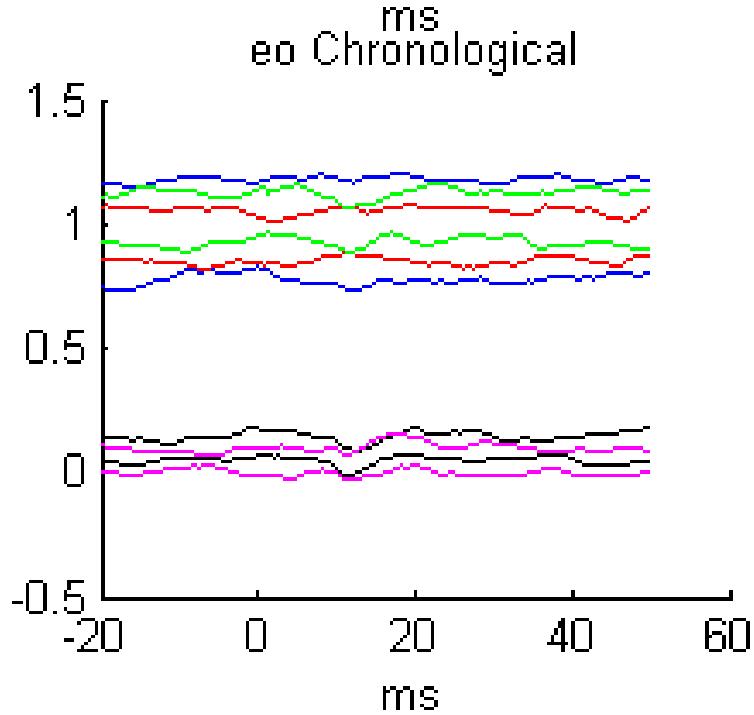
•Chronology/fatigue

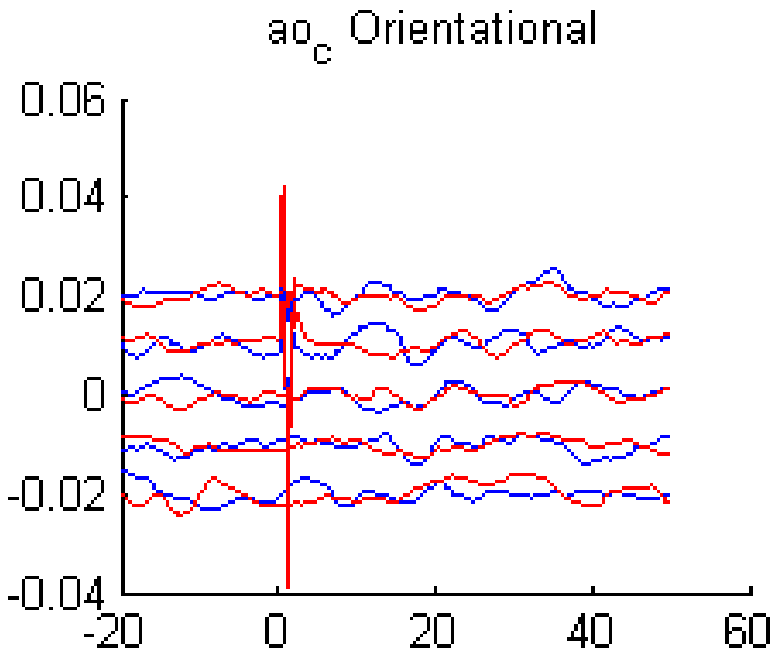
•Responses were considered "reliable" when the p1 and n1 peaks occurred during the appropriate time intervals and if the peak-peak amplitude was greater than twice the peak noise level in the 20 msec prior to the click

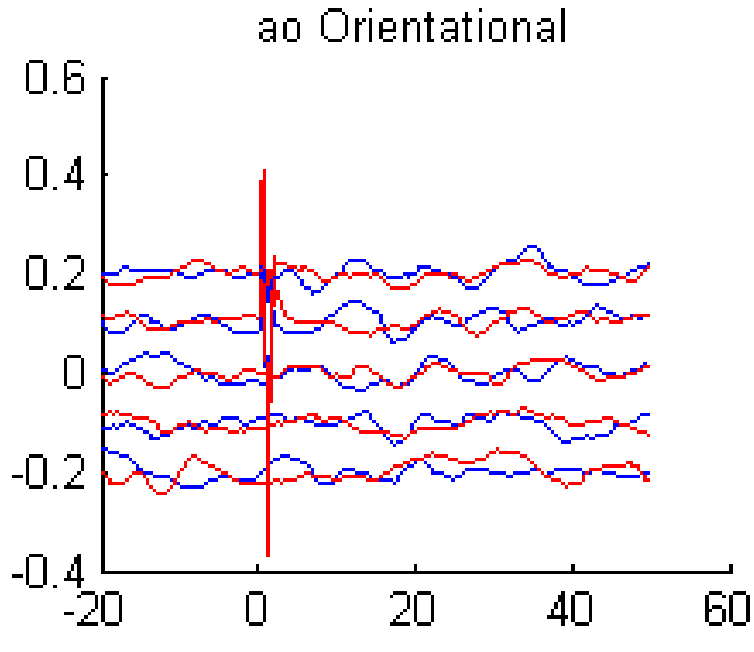

eo$_c$ Orientational
0.04
0.02
0
-0.02
-0.04
-20
0
20
40
60

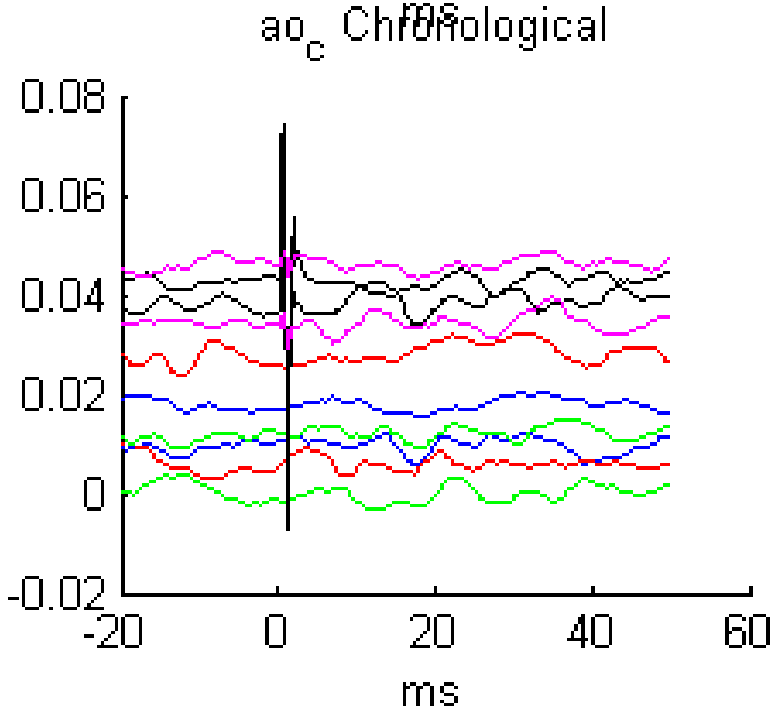

eo Orientational
0.4
0.2
0
-0.2
-0.4
-20
0
20
40
60
ms

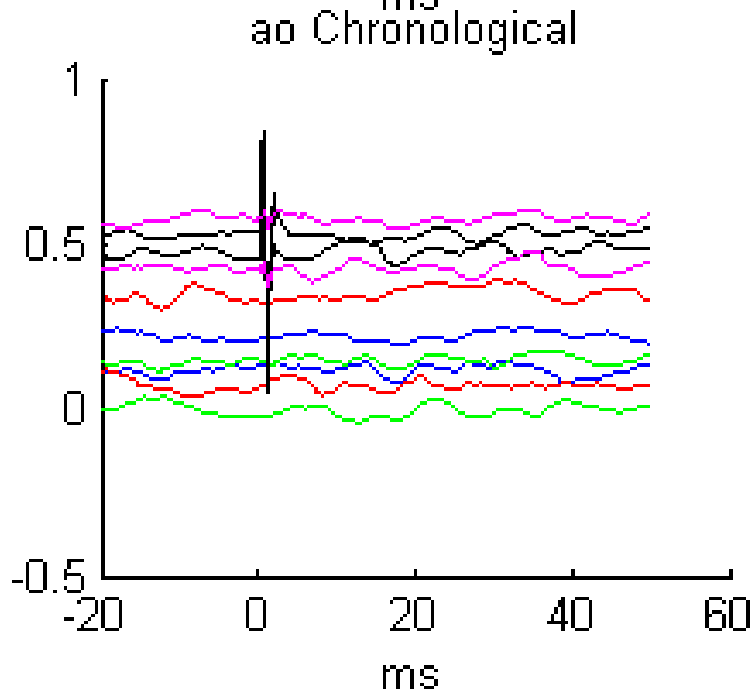

eo$_c$ Chronological
0.15
0.1
0.05
0
-0.05
-20
0
20
40
60
ms

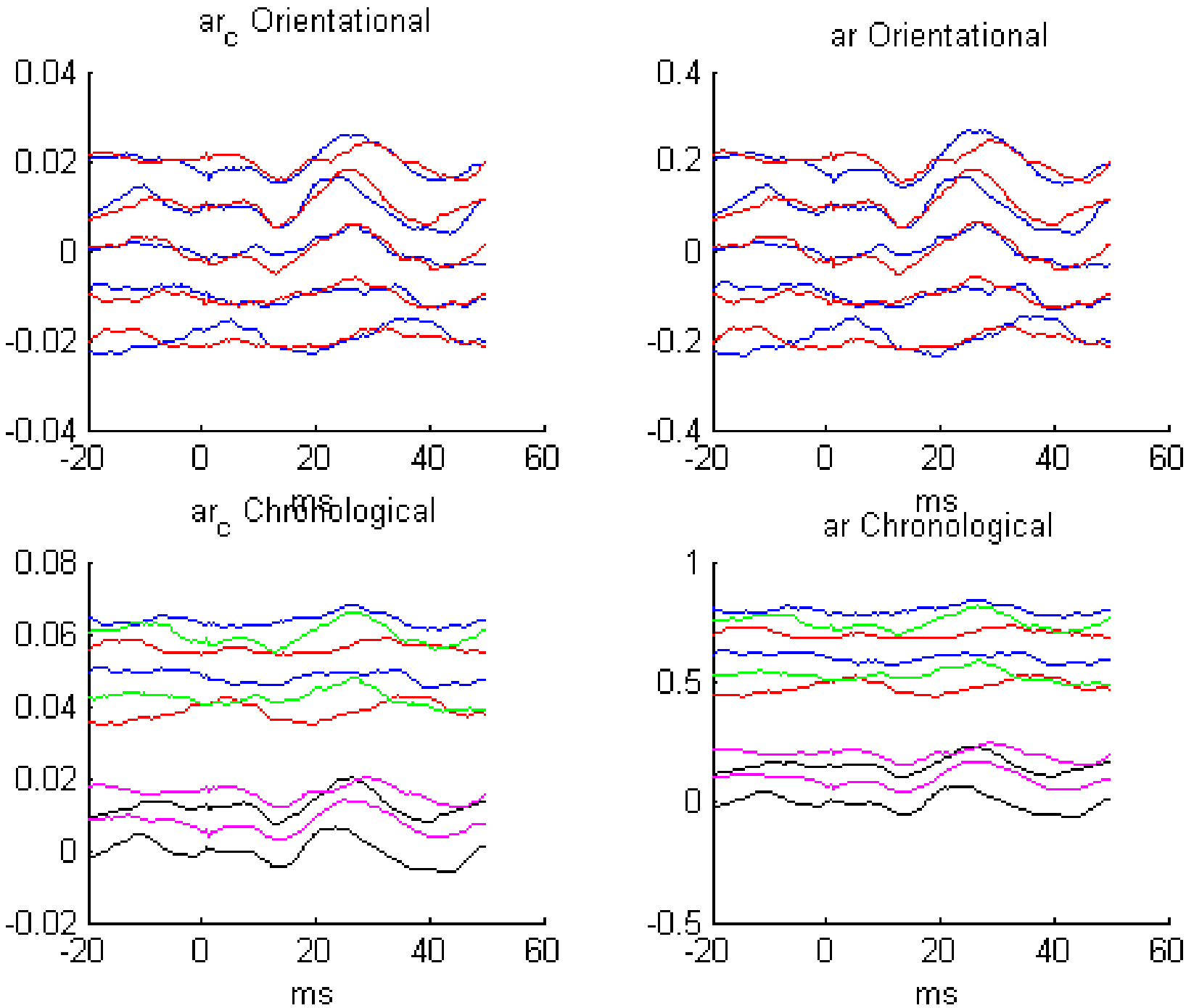

eo Chronological
1.5
1
0.5
0
-0.5
-20
0
20
40
60
ms

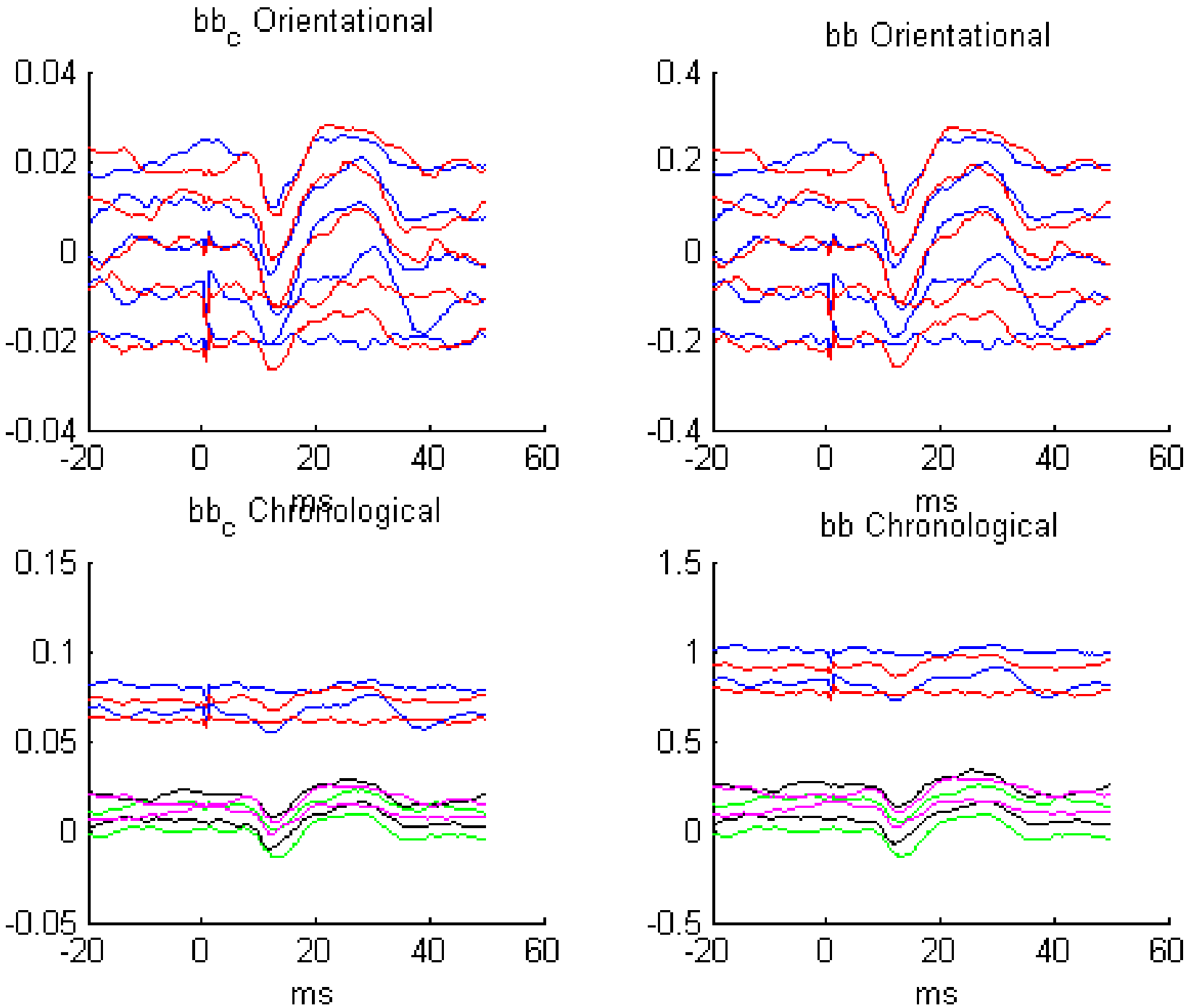

ao$_c$ Orientational
0.06
0.04
0.02
0
-0.02
-0.04
-20
0
20
40
60

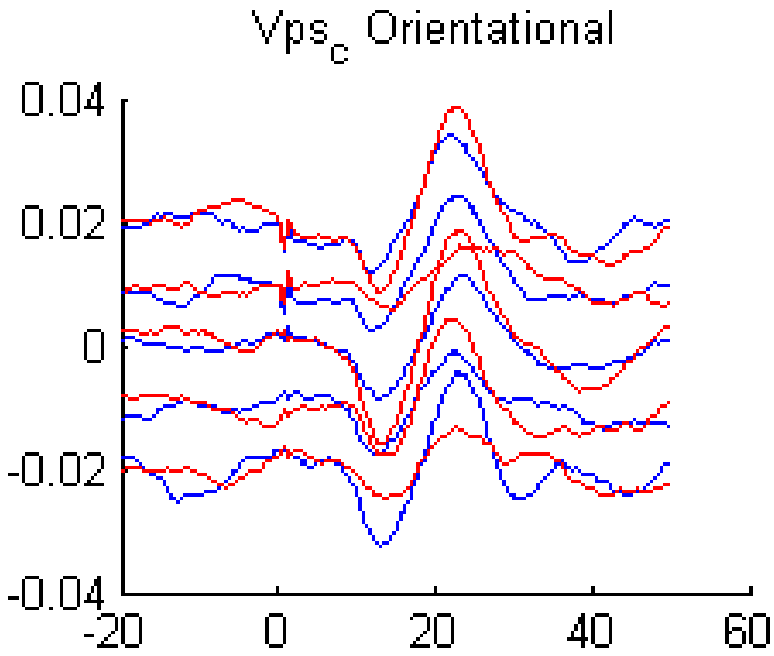

ao Orientational
0.6
0.4
0.2
0
-0.2
-0.4
-20
0
20
40
60
ms

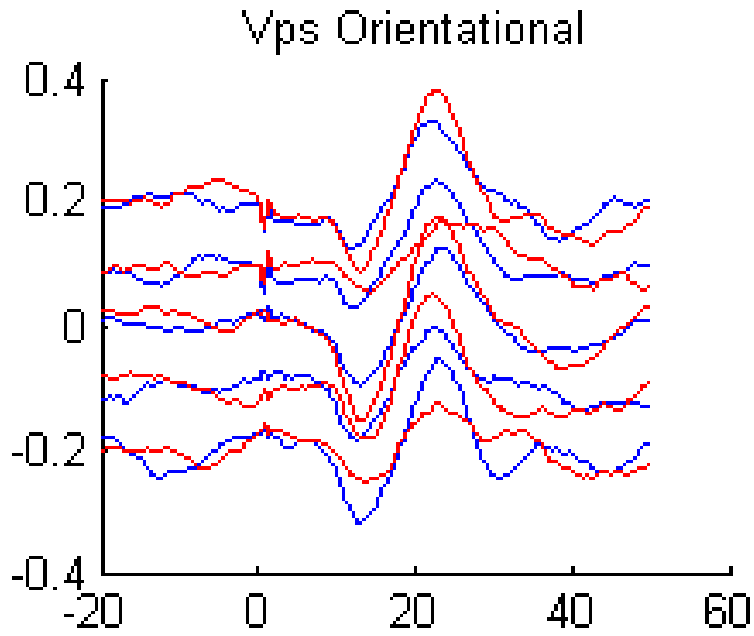

ao$_c$ Chronological
0.08
0.06
0.04
0.02
0
-0.02
-20
0
20
40
60
ms

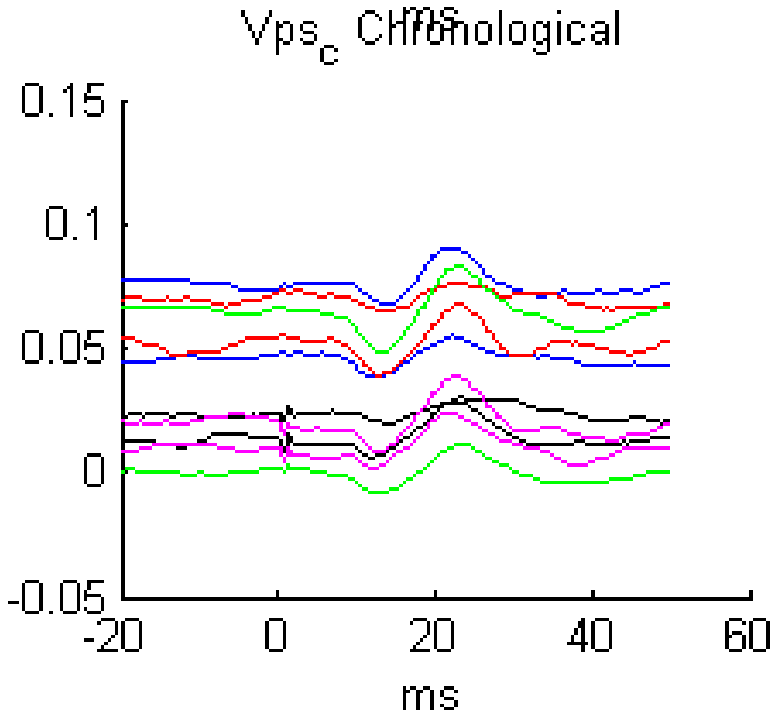

ao Chronological
1
0.5
0
-0.5
-20
0
20
40
60
ms

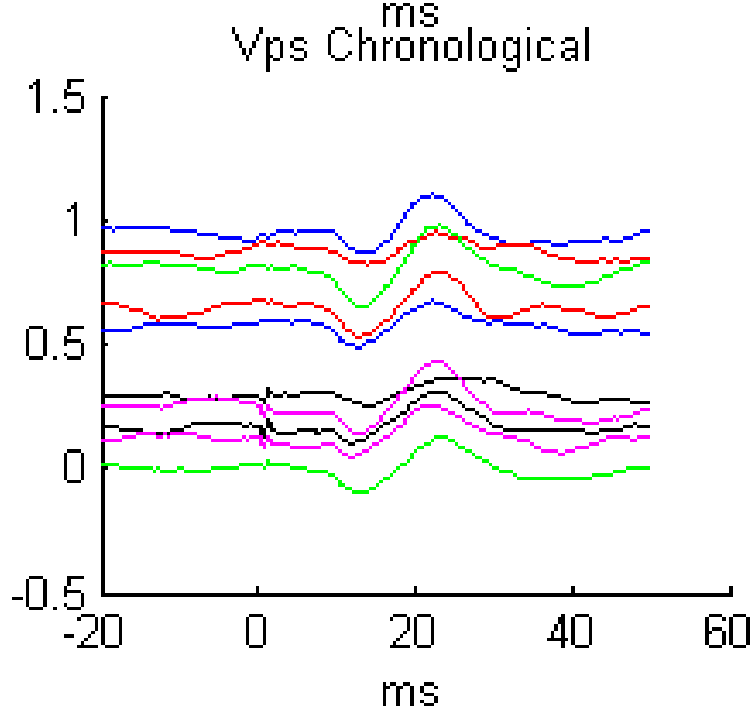

ar_c Orientational
0.04
0.02
0
-0.02
-0.04
-20
0
20
40
60
ar Orientational
0.4
0.2
0
-0.2
-0.4
-20
0
20
40
60
ms
ar_c Chronological
0.08
0.06
0.04
0.02
0
-0.02
-20
0
20
40
60
ms
ar Chronological
1
0.5
0
-0.5
-20
0
20
40
60
ms


bb$_c$ Orientational
0.04
0.02
0
-0.02
-0.04
-20
0
20
40
60
bb Orientational
0.4
0.2
0
-0.2
-0.4
-20
0
20
40
60
ms
bb$_c$ Chronological
0.15
0.1
0.05
0
-0.05
-20
0
20
40
60
ms
bb Chronological
1.5
1
0.5
0
-0.5
-20
0
20
40
60
ms

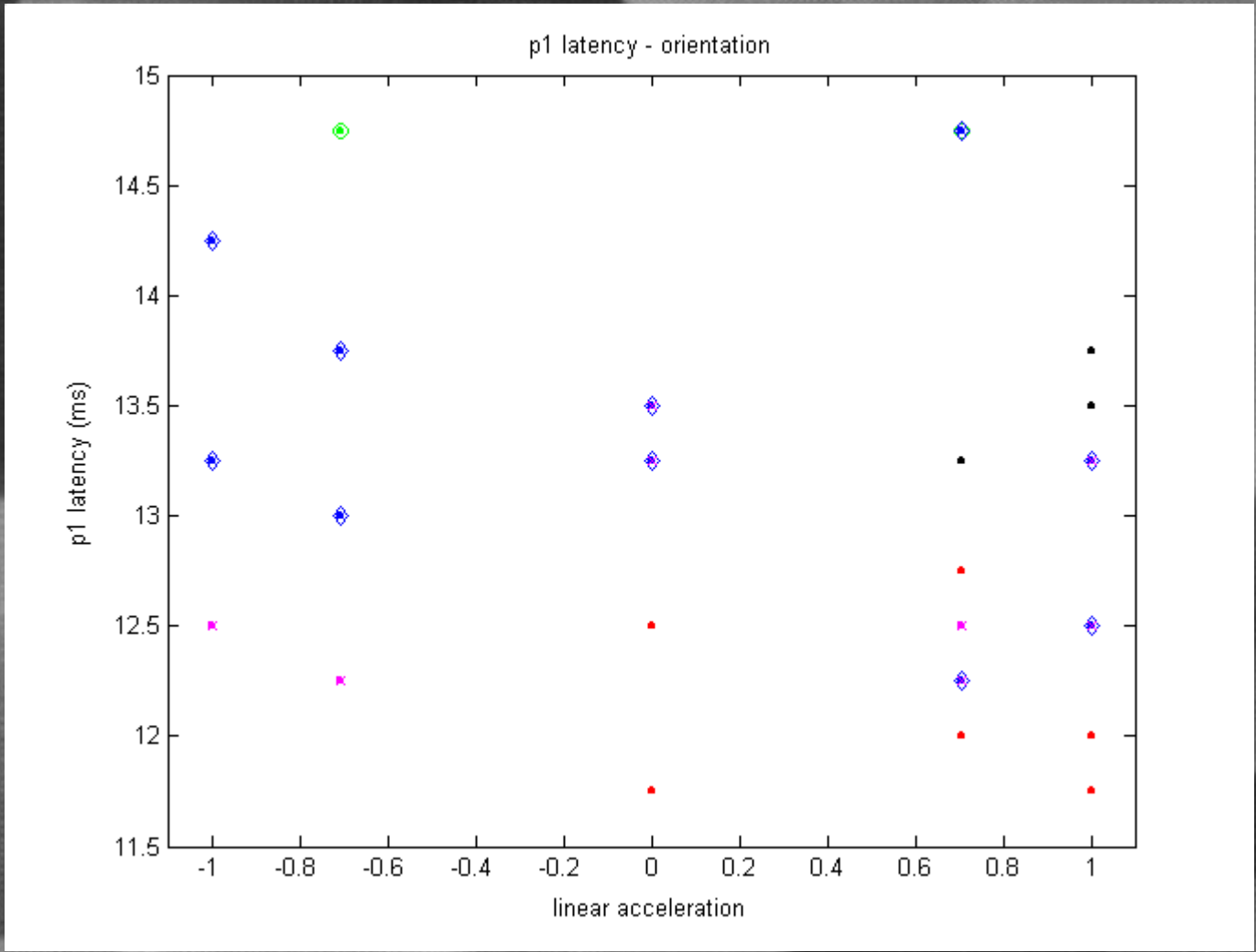

Vps$_c$ Orientational
0.04
0.02
0
-0.02
-0.04
-20
0
20
40
60
ms


Vps Orientational
0.4
0.2
0
-0.2
-0.4
-20
0
20
40
60
ms

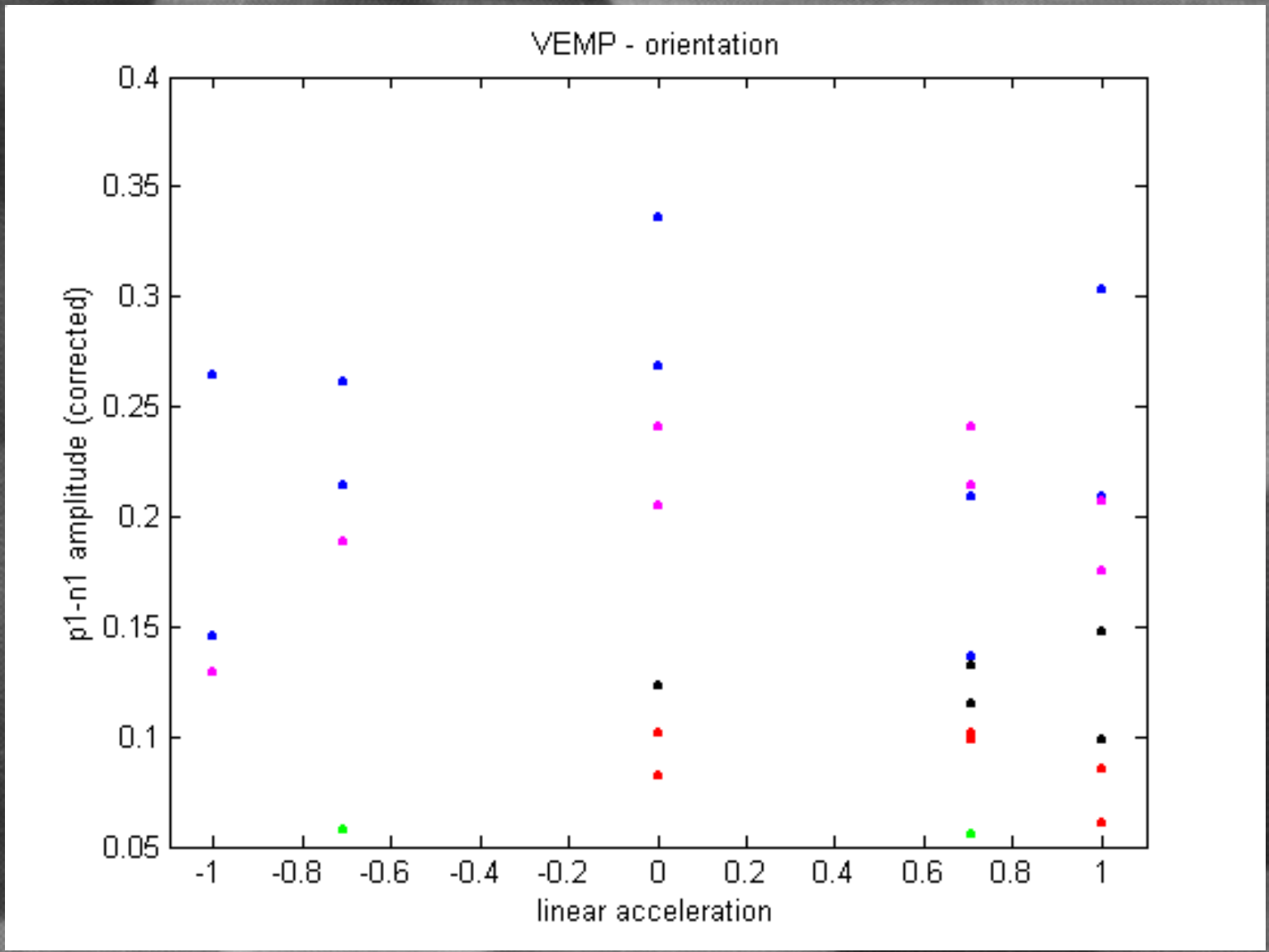

Vps$_c$ Chronological
0.15
0.1
0.05
0
-0.05
-20
0
20
40
60
ms


Vps Chronological
1.5
1
0.5
0
-0.5
-20
0
20
40
60
ms

Latency

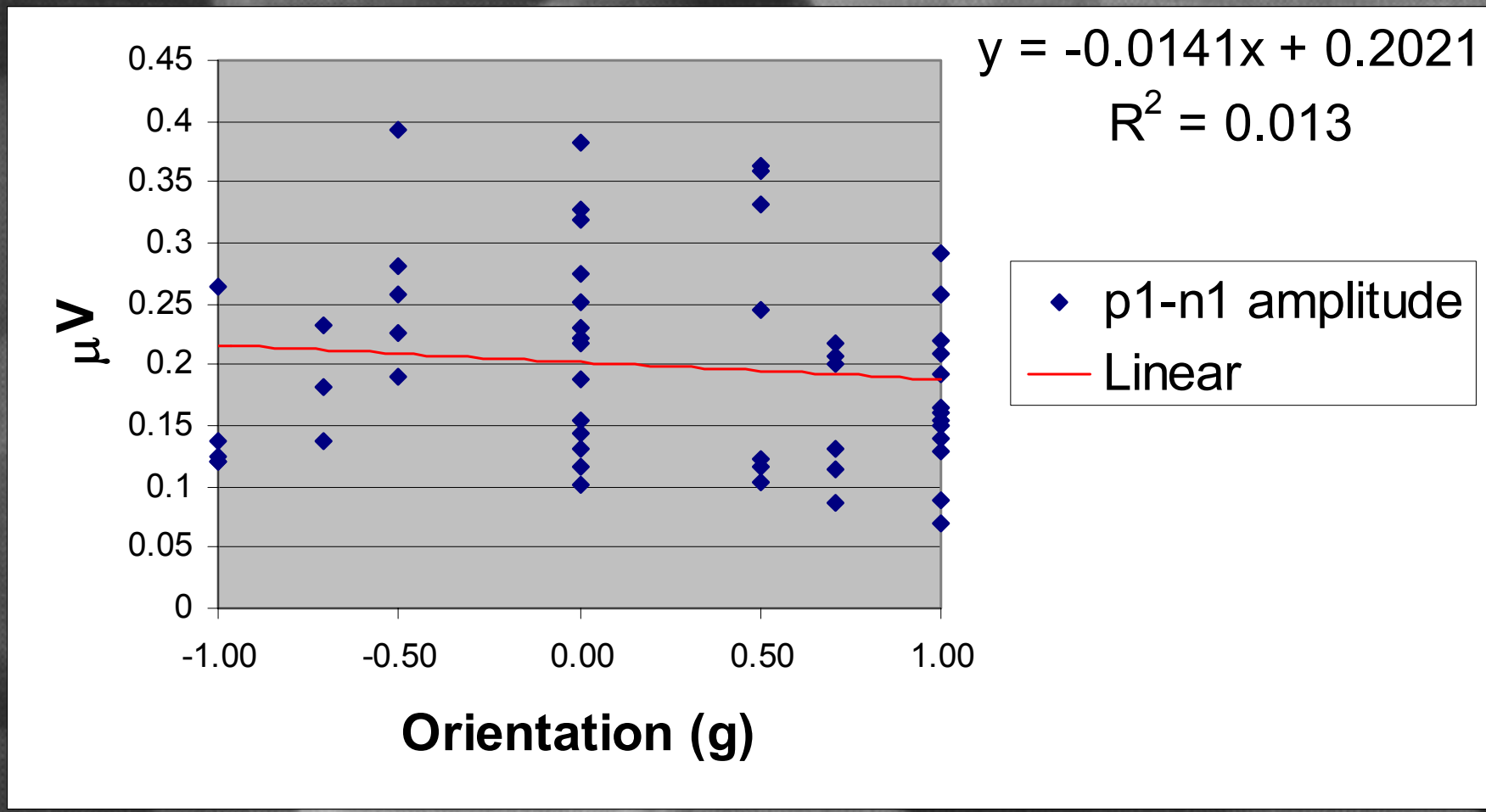

p1 latency - orientation
p1 latency (ms)
15
14.5
14
13.5
13
12.5
12
11.5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
linear acceleration

Round 1 amplitudes



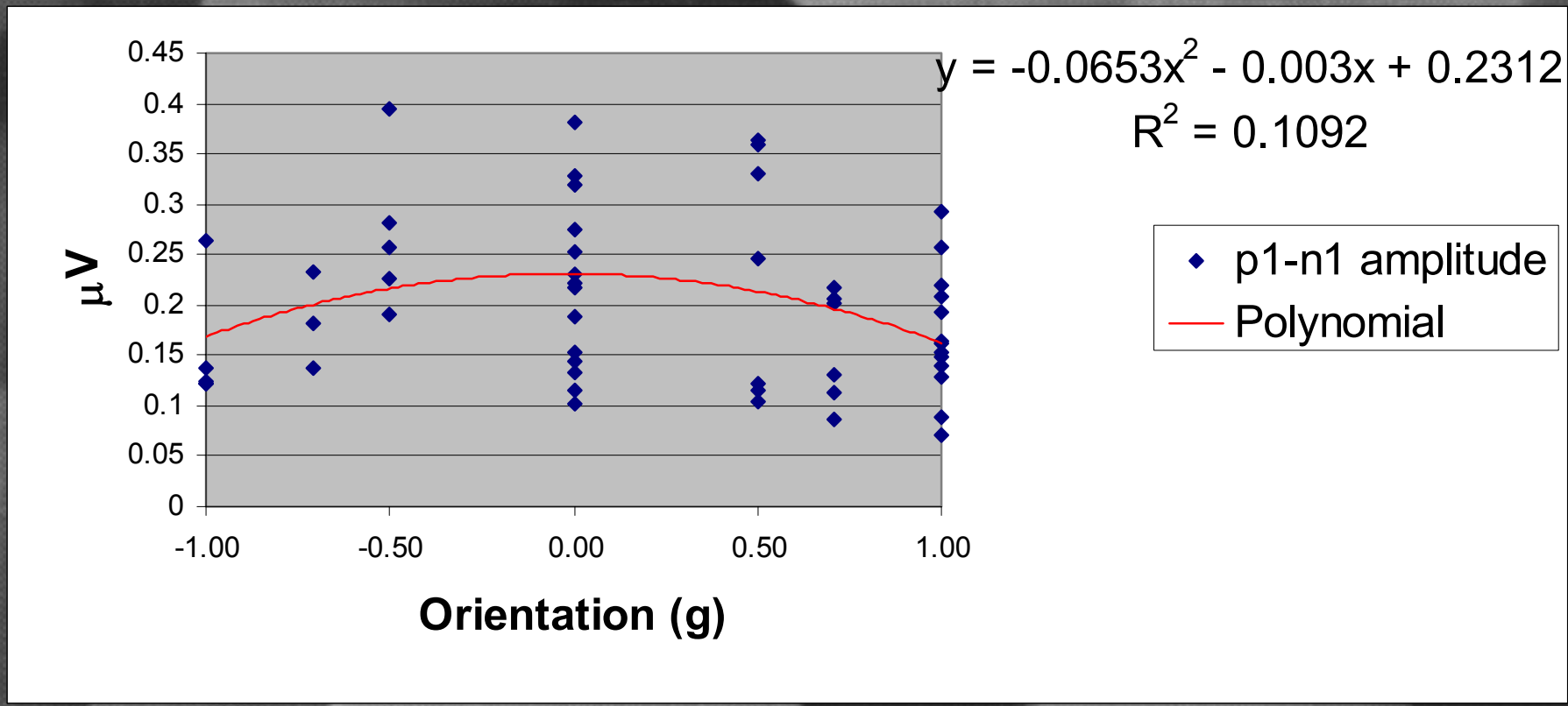
Strict criteria

53 reliable averages from 10 normal subjects



Strict criteria

53 reliable averages from 10 normal subjects



Expected				
	response?(%)			
-1.00	31.18			
-0.71	31.18			
-5.00	31.18			
0.00	31.18			
0.50	31.18			
0.71	31.18			
1.00	31.18			
Actual				
	response?(%)		response	no response
-1.00	14.71		5	29
-0.71	18.75		3	13
-0.50	27.78		5	13
0.00	41.18		14	20
0.50	38.89		7	11
0.71	37.50		6	10
1.00	38.24		13	21
Chi-Test				
	0.001200198			

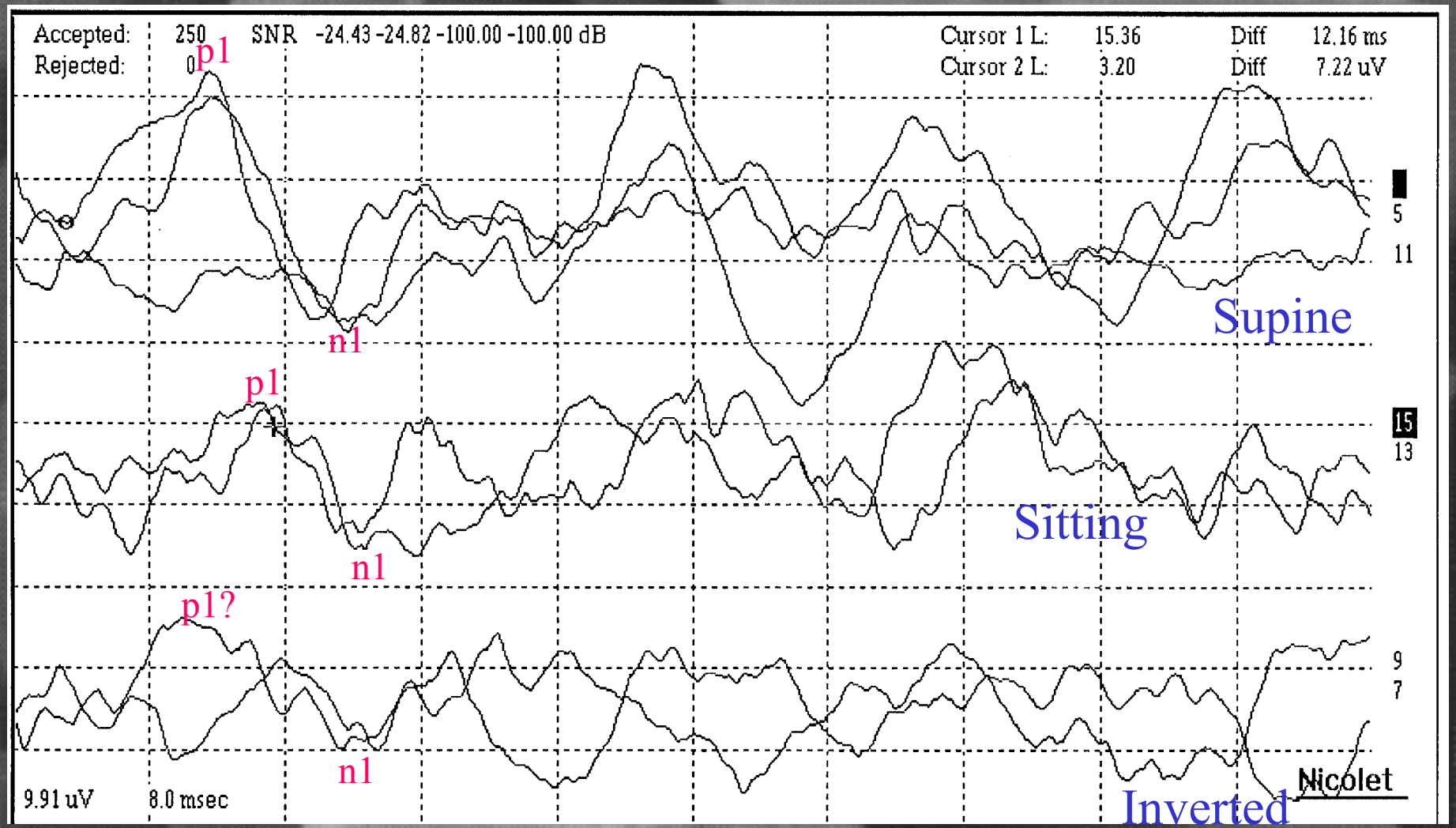
Disproportionate number of "unreliable" responses were in inverted orientations

How to distinguish a response with an amplitude below noise level from "noisy data?"

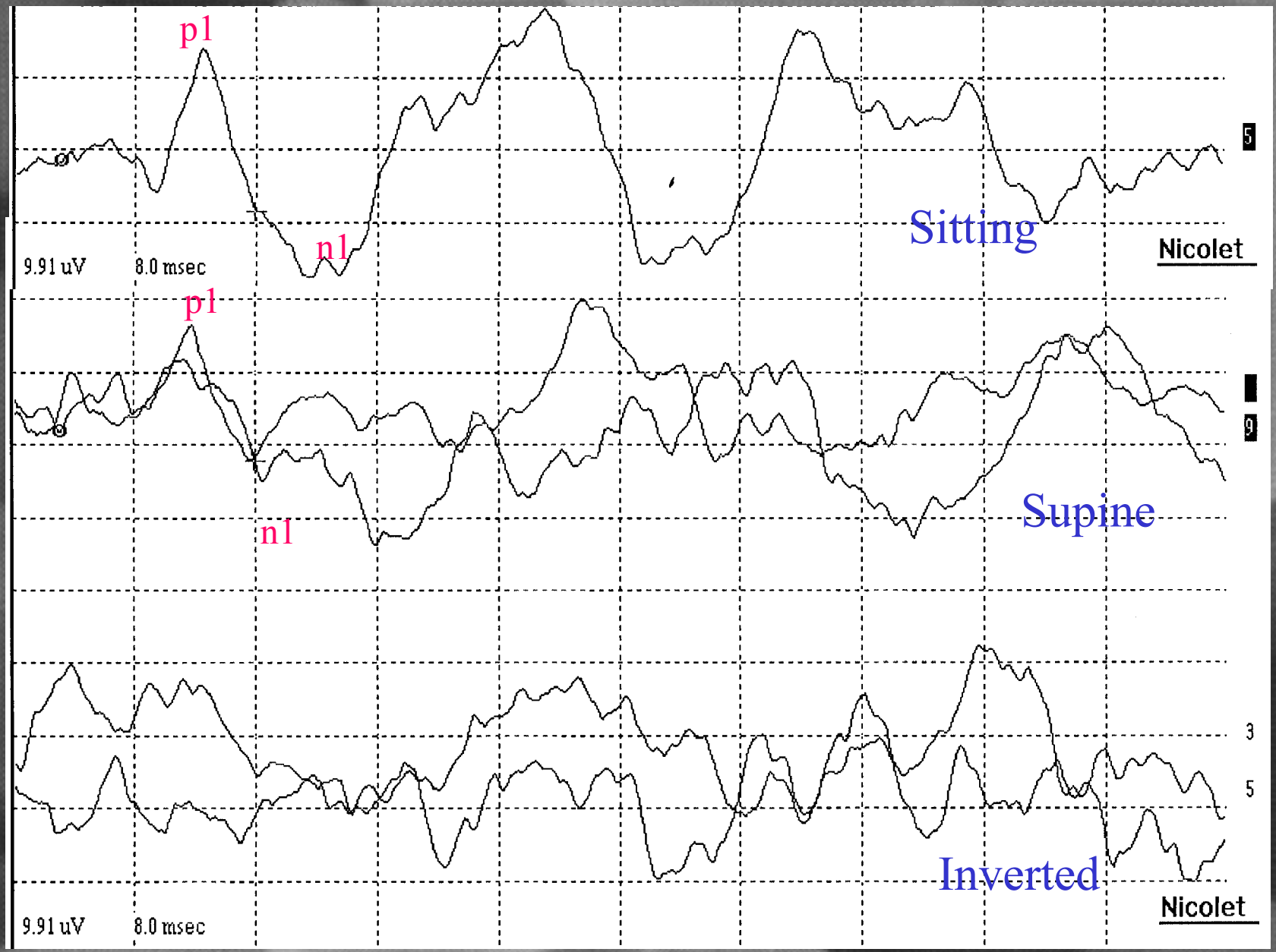
(Includes 20 trials from subjects tested in clinical laboratory)

Clinical laboratory testing

ds

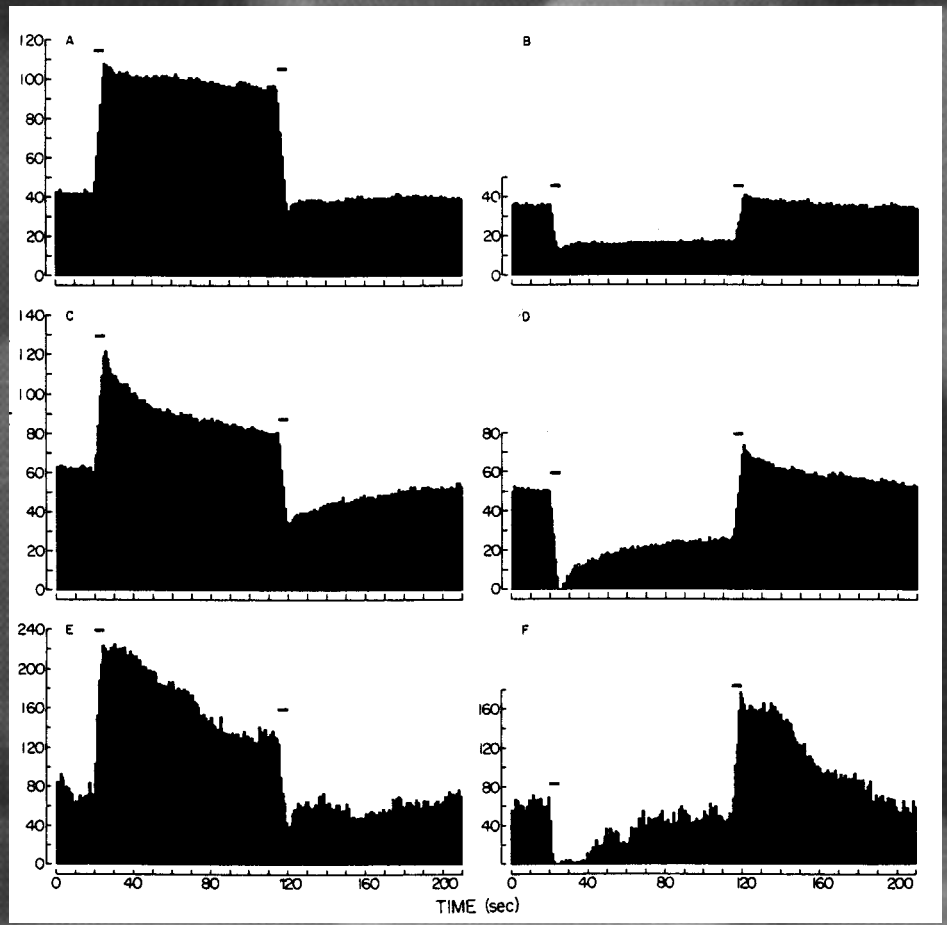


aj


p1
n1
9.91 uV
8.0 msec
Sitting
Nicolet
5
p1
n1
Supine
9
3
5
Inverted
9.91 uV
8.0 msec
Nicolet

Response to trapezoidal changes in gravito-inertial acceleration

Excitatory Inhibitory



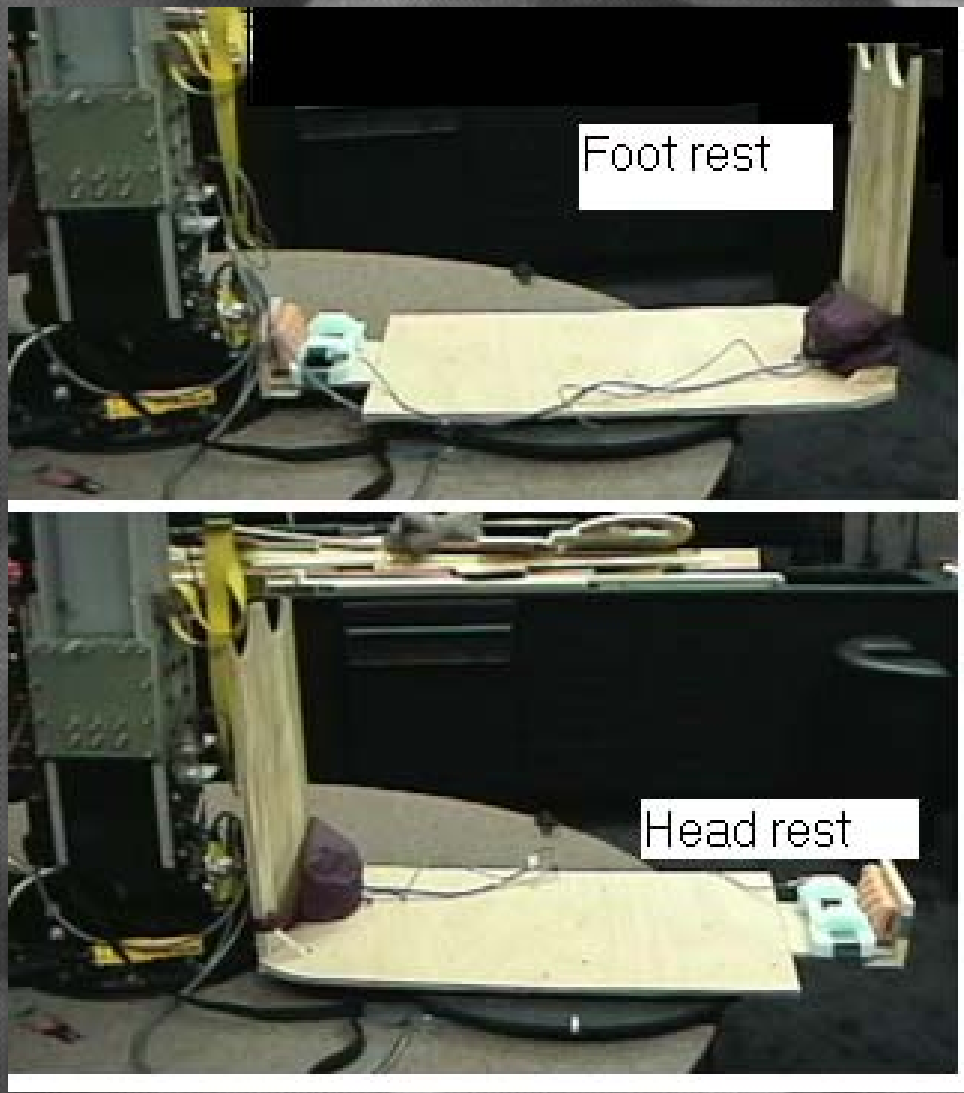
Irregular unit from inferior division

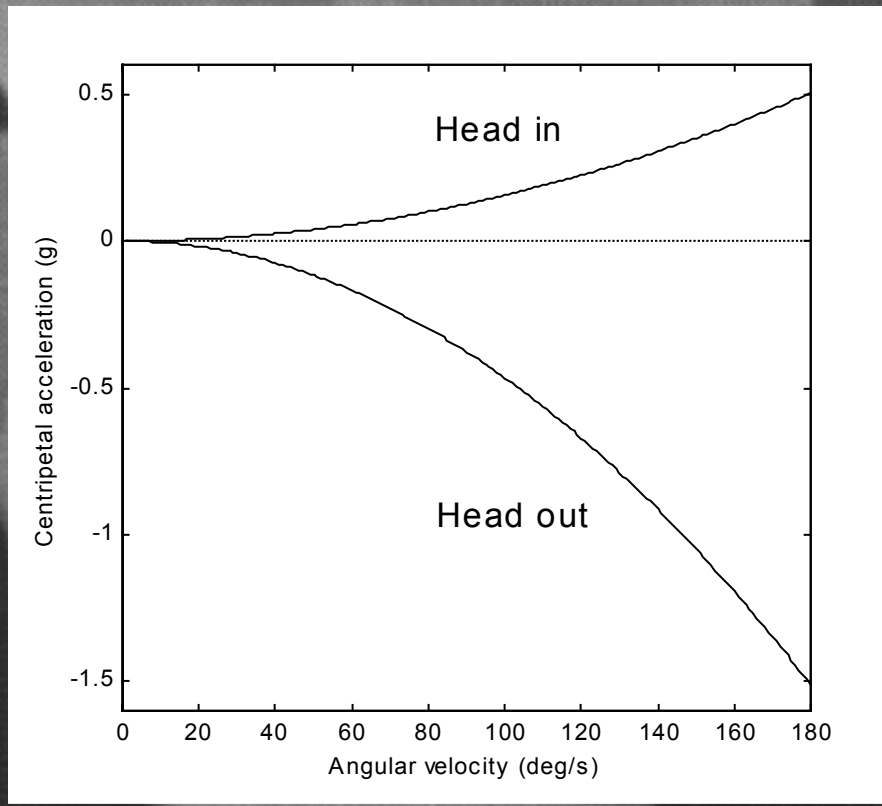
Adaptation over 100 seconds

Relevance to spaceflight and artificial gravity

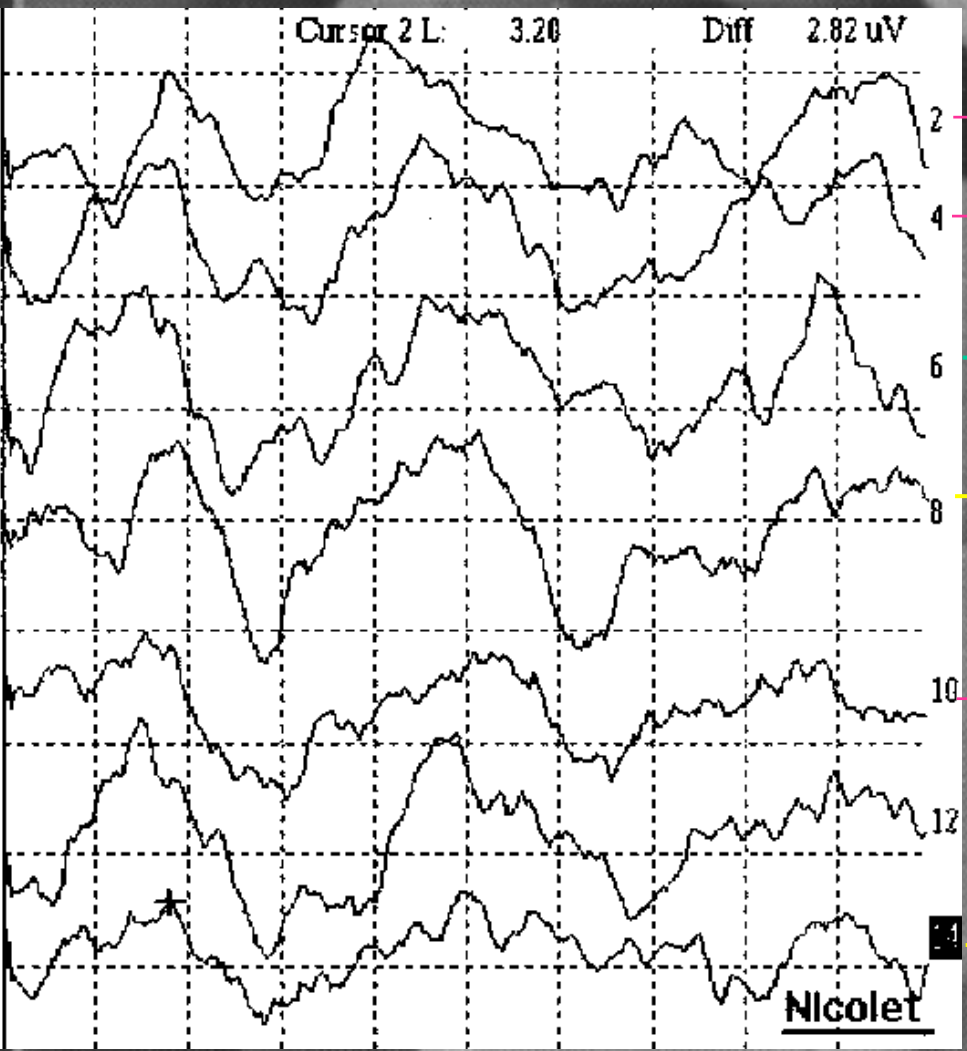
- When ‘unloaded’ there is a difference in spontaneous firing rate of saccular units excited by either rostral (+Z) or caudal (-Z) directed acceleration
- Resting saccular discharge rates were significantly higher for -Z units than for +Z units
- Therefore when upright, units in the saccule responding to upward acceleration will be statically excited by gravity, and downward responding units inhibited
- Does this differential in firing rate adapt during long-duration microgravity exposure?
- Can the VEMP provide a rapid, non-invasive picture of saccular afferent activity?

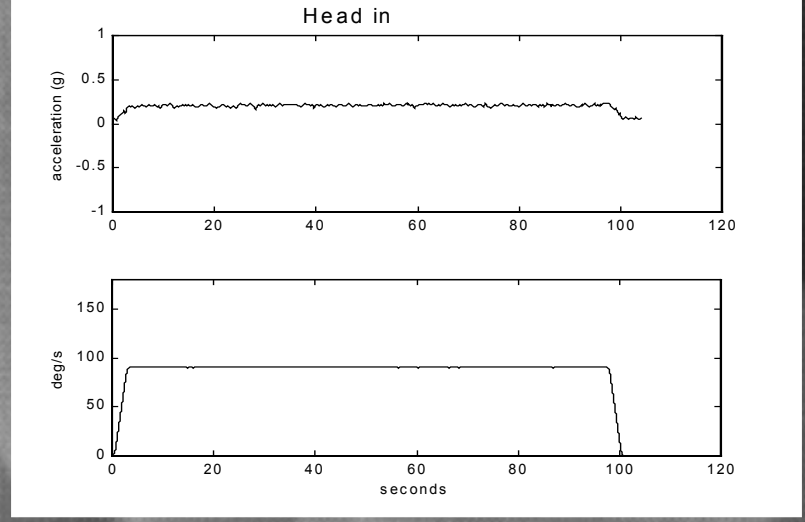
Short-arm centrifuge





> 1g accelerations





Baseline supine

+z 0.5g

−x 1g

Supine, immediately post centrifugation


774
208
961