THE ART OF LIFE IS A CONSTANT READJUSTMENT TO OUR SURROUNDINGS:
PHYSIOLOGICAL CHANGES AFTER USING AN EARPLUG

Kevin J Munro, Jen Blount & Joannie Marriott

School of Psychological Sciences
Faculty of Medical and Human Sciences
The University of Manchester
kevin.munro@manchester.ac.uk

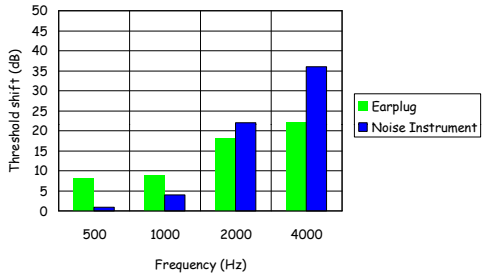
HYPERACUSIS

1. anomaly of loudness perception: intolerance for sound levels that are normally judged to be comfortably loud
2. prevalence ca 8% in general population
3. frequent co-occurrence with tinnitus
4. Mechanism commonly explained as abnormally high 'central gain'
5. treatment:
   - hearing protection to minimize sound exposure
   - sound therapy (desensitization OR recalibration)

FORMBY et al
(JASA, 2003,114, 55-58)

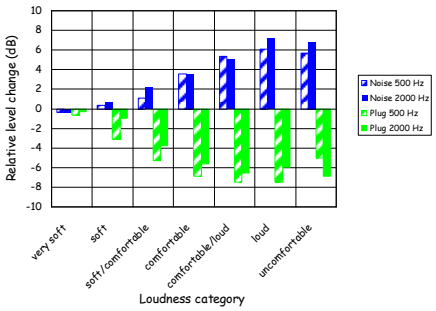
- Measured loudness rating in 10 normal-hearing adults pre & post treatment
- Two sound treatments:
  - earplugs (attenuation)
  - broadband noise generating instruments (enrichment)
- Two weeks of continuous bilateral use

MEAN THRESHOLD SHIFT WITH TREATMENT



[Adapted from Fig 1, Formby et al, 2003]

MEAN CHANGE IN LOUDNESS JUDGEMENTS



(tolerance increased after noise & decreased after plugs AND at both frequencies)

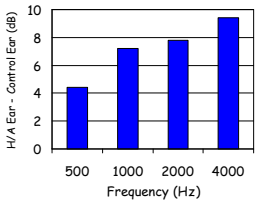
[Data from Table 1, Formby et al, 2003]

- Evidence of adaptive plasticity of loudness
- Consistent with central gain mechanism; alternatively, could be a recalibration of behavioural criteria for loudness
  - e.g., after attenuation, central gain increased OR more conservative behavioural criterion
- To differentiate between the two speculative mechanisms, one needs direct evidence of plasticity

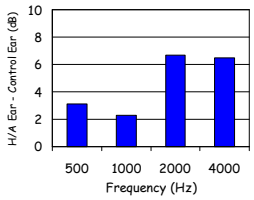
MUNRO et al
(NeuroReport, 2007, 18,1237-40)

- Unilateral HA users (n=16) for 3 years, 10 hr/day

ASYMMETRY IN ULLs



ASYMMETRY IN ARTs



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DOES THE ACOUSTIC REFLEX THRESHOLD CHANGE AFTER A PERIOD OF EARPLUG-INDUCED DEPRIVATION?

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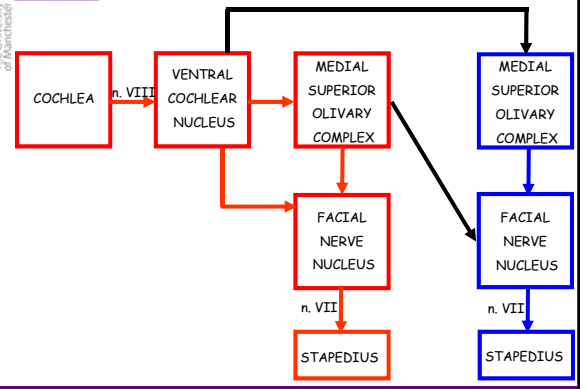
REFLEX PATHWAYS FOR RIGHT STIMULATION



[Adapted from Wiley & Block, 1984]

9

HYPOTHESIS: THERE WILL BE AN ASYMMETRY IN ART AFTER UNILATERAL DEPRIVATION, WITH LOWER ARTS IN THE PLUGGED EAR

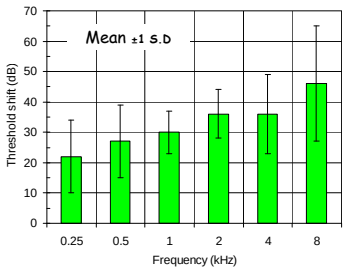
10

METHODS

- 11 normal-hearing participants
  - 24 years (s.d. 2.4)
  - 8 F & 3 M
  - hearing thresholds <20 dB HL (0.25-8 kHz)
  - middle ear function WNL on tympanometry
- Custom made earplug for one ear
  - 5 R & 6 L
  - Durable biopore (shore rating of 25)
  - Continuous earplug use for 7 days

11

MEAN THRESHOLD SHIFT WITH TREATMENT



(15-20 dB greater than Formby et al, 2003)

12

TREATMENT EAR

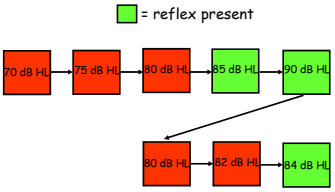
Day 0 — EARPLUG — Day 7 — NO EARPLUG — Day 14

CONTROL EAR

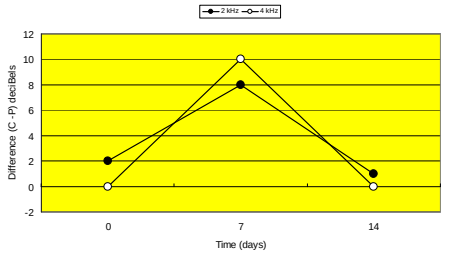
Day 0 — NO EARPLUG — Day 7 — NO EARPLUG — Day 14

IPSILATERAL ARTS AT 2 & 4 kHz

- GSI Tympstar middle ear analyzer
- 70 dB HL & +5 dB steps until ≥0.02 ml decrease in admittance
- Increase +5 dB to confirm growth of reflex
- Reduce 10 dB & increase +2 dB steps to determine threshold

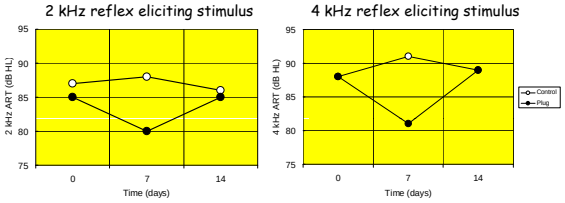


RESULTS: EAR ASYMMETRY



2-factor repeated-measures ANOVA revealed TIME to be statistically significant but not FREQUENCY and no interaction.

RESULTS: MEAN ARTs



2-factor repeated-measures ANOVA revealed statistically significant INTERACTION between time & ear (at each frequency)

HOW GENERALISABLE?

- 2 kHz eliciting tone, ten (91%) lower ARTs in plug ear (in 7 [64%] asymmetry ≥8 dB)
- 4 kHz eliciting tone, 11 (100%) lower ARTs in plug ear (in 7 [64%] asymmetry ≥10 dB)
- The participants who showed a change at 4 kHz were the same ones who showed a change at 2 kHz (0 & 7 days: r=0.83, n=11, p<0.01; 7 & 14 days: r=0.71, n=11, p=0.02)

CLEAR DEMONSTRATION OF THE INFLUENCE OF EXPERIENCE ON SENSORY PROCESSING IN AUDITORY BRAINSTEM

EXPERIENCE DEPENDENT PLASTICITY IN AUDITORY BRAINSTEM

1. LIFE LONG EXPERIENCE
   - LANGUAGE EXPERIENCE e.g., Krishnan et al (2005),
   - MUSICAL TRAINING e.g., Musacchia et al (2007); Wong et al (2007)
   - LANGUAGE IMPAIRMENT e.g., Cunningham et al (2001); Banai et al (2009), Russo et al (2008)
2. MEDIUM TERM EXPERIENCE
   - HEARING AIDs e.g. Munro et al (2007a,b)
3. SHORT TERM EXPERIENCE
   - AUDITORY TRAINING e.g., Russo et al (2005); Song et al (2008), de Boer & Thornton (2008)
   - UNILATERAL DEPRIVATION e.g., Munro & Blount (2009)

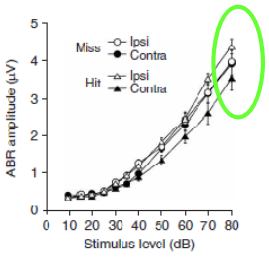
FINDINGS IN PRESENT STUDY PROVIDE PHYSIOLOGICAL BASIS FOR THE GAIN CONTROL THEORY

WHY CHANGES IN BOTH EARS?

Cochlear efferent feedback balances interaural sensitivity

Keith N Darrow[1,2], Stephane F Maison[2,3] & M Charles Liberman[1,3]

Neurons in the lateral superior olive (LSO) compute sound location based on differences in interaural intensity, coded in ascending signals from the two cochleas. Unilateral destruction of the neuronal feedback from the LSO to the cochlea, the lateral olivocochlear efferents, disrupted the normal interaural correlation in response amplitudes to sounds of equal intensity. Thus, lateral olivocochlear feedback maintains the binaural balance in neural excitability required for accurate localization of sounds in space.

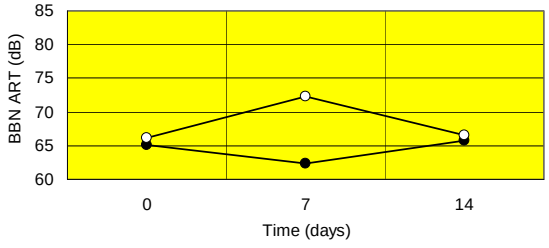


RELEVANCE TO HYPERACUSIS?

- Known relationship between ULL & ART
- Reduced ART probably means reduced ULL i.e., less tolerance for loud sounds
  - Formby et al reported changes in loudness rating after bilateral earplug experience
  - We have yet to systematically investigate loudness rating & ART (but many participants report: i] tinnitus during earplug use, and ii] loudness intolerance immediately after earplug removal)

FREQUENCY EFFECTS (Marriott & Munro, n=12)

Plug ear, filled symbols; Control ear, open symbols



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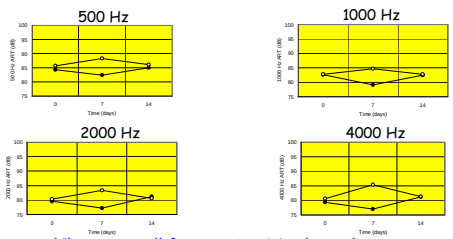
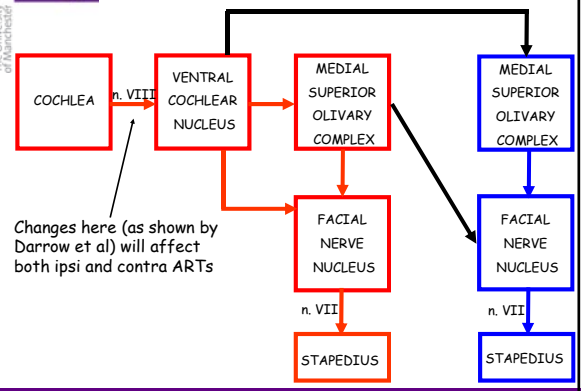


(Changes at all frequencies & both ears)

- generalised changes across frequencies (despite earplug mainly affecting high frequencies)
- Formby et al showed changes in loudness at high & low frequencies
- hyperacusis generally affects all frequencies

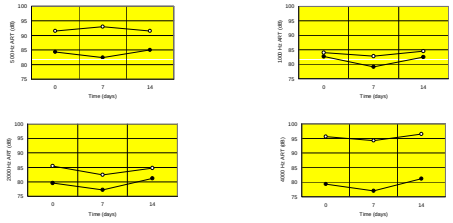
REFLEX PATHWAYS FOR RIGHT STIMULATION



[Adapted from Wiley & Block, 1984]

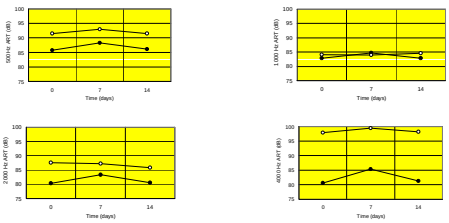
CONTRALATERAL EFFECTS
(Marriott & Munro, n=12)

ELICITING STIMULI IN PLUGGED EAR:
ipsi, filled symbols; contra, open symbols



CONTRALATERAL EFFECTS
(Marriott & Munro, n=12)

ELICITING STIMULI IN CONTROL EAR:
ipsi, filled symbols; contra, open symbols



TAKE-HOME MESSAGE

1. clear demonstration of experience-related changes in sensory processing in adult auditory brainstem
2. results consistent with a change in central gain
3. findings suggest that using earplugs will not help individuals with hyperacusis