The role of functional near-infra-red spectroscopy (fNIRS) in early intervention for infants with hearing impairment

Colette McKay

…and EarGenie team

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The EarGenie Team

BI TEAM

Dr Julia Wunderlich (Clinical Lead)
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Dr Demi Gao (Research Engineer)
Linty McDonald (Audiologist)
Steven Lee (PhD student/Audiologist)
Suwana Watt (Audiologist)

DEVELOPMENT/COMMERCIALISATION

NIRGenie company: CEO Dr Jeffry Ng
Prototyping partner: Design + Industry

Our aim…closing the gaps

….between **identification** of hearing loss in an infant and the **accurate fitting of the optimal hearing instrument**

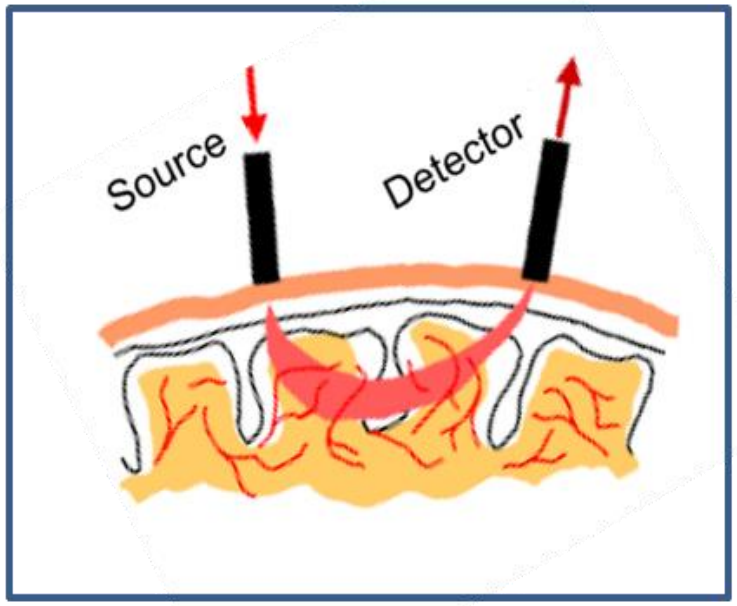
- **Auditory neuropathy…**what is my functional hearing like?
  - Sensitivity and discrimination
- **All infants…**
  - is my hearing aid programmed optimally (sound detection)?
  - and would a cochlear implant be a better option (discrimination)?
- **Cochlear implants…**objective programming and evaluating early programs

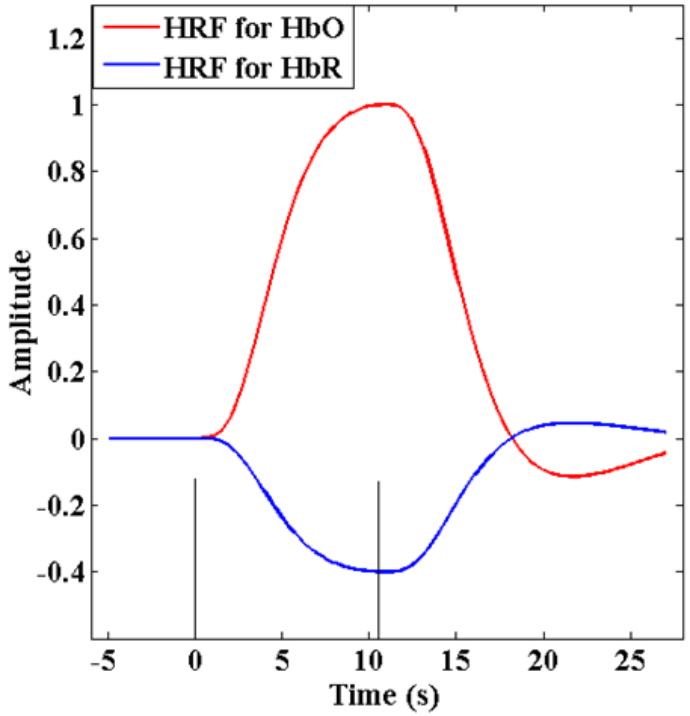
What do we need to **fast track** intervention…?

- A reliable and accurate objective test of speech sound detection and discrimination that is
  - Reliable for infants with auditory neuropathy
  - Suitable for very young infants in the natural sleep state
  - Suitable for use in cochlear implants (not affected by electrical artifacts or interference)

Introducing EarGenie

The hearing assessment system that uses fNIRS





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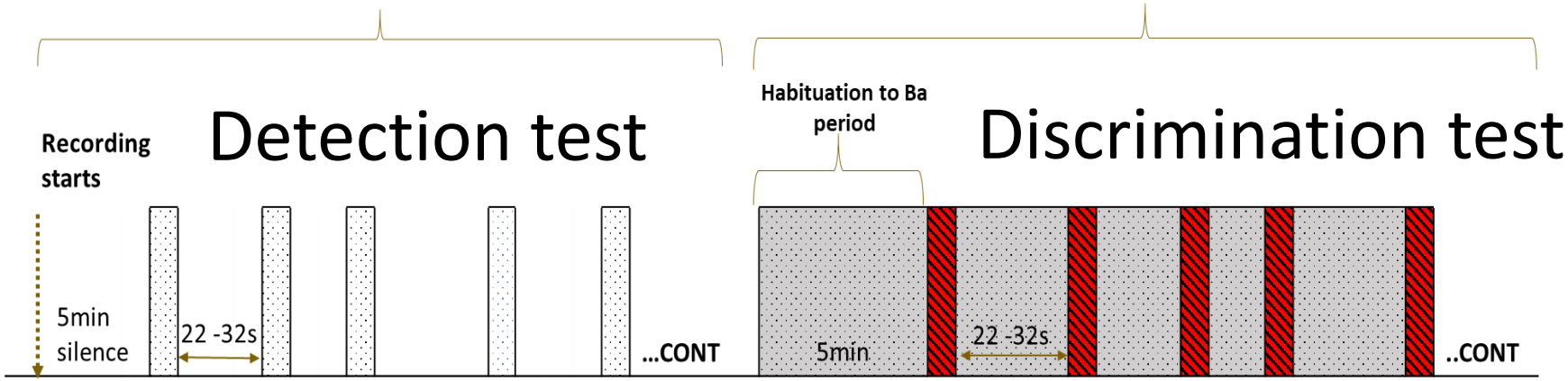
Speech Detection and Discrimination



Standard block: BaBaBaBaBaBa

Repeated Ba baseline

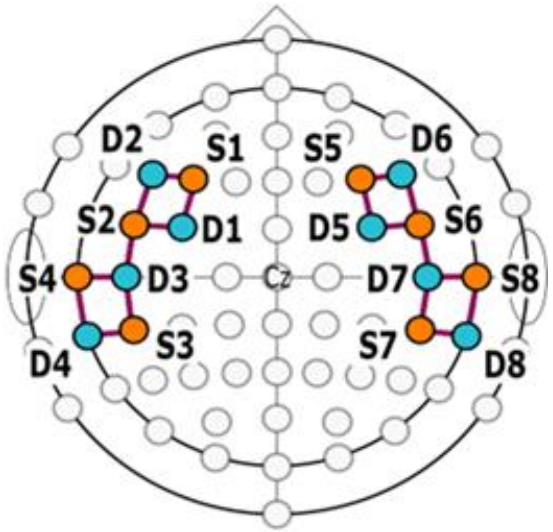
Novel block: CBaCBaCBaCBa

C = Contrast speech sound to be tested

In each test run, C is pseudorandomised within a set of 3 contrasts.

Set 1 contrast sounds:
Tea/Ba, Bee/Ba, Ga/Ba

Set 2 contrast sounds:
Tea/Ba, Pa/Ba, Ma/Ba



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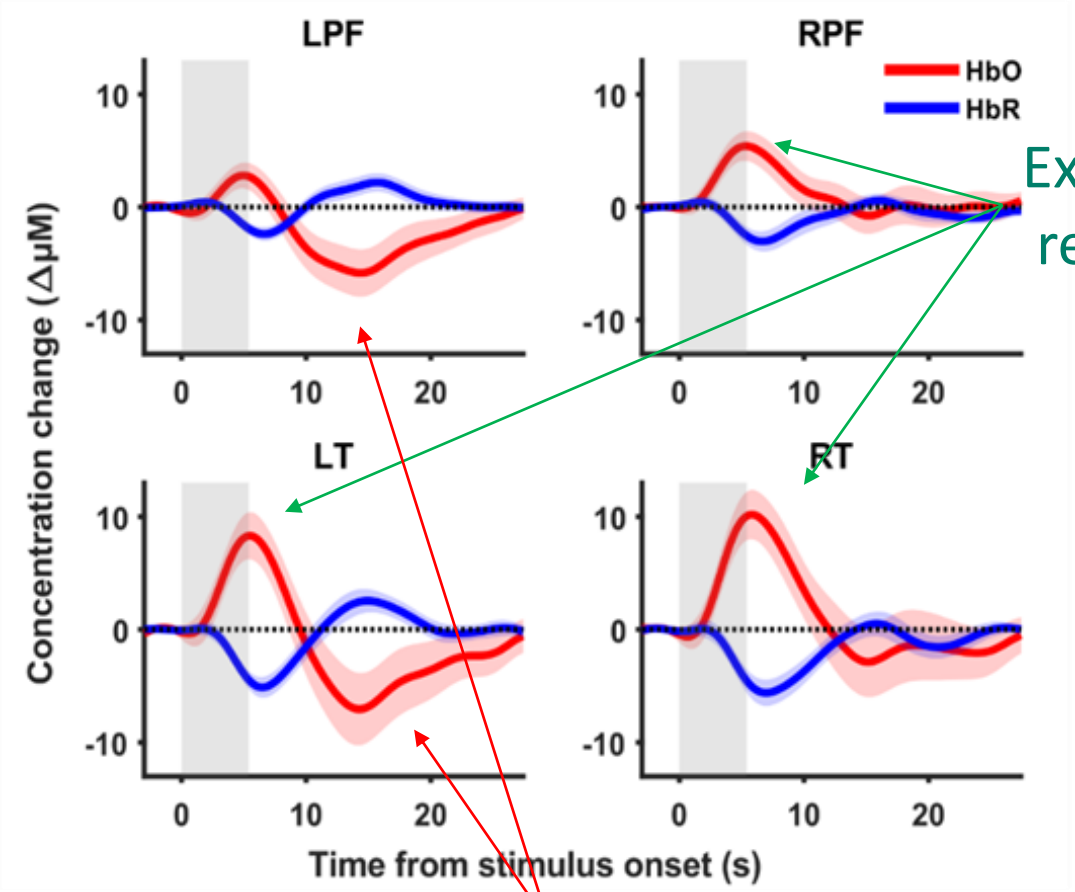
Detection response 65 dB SPL
(n = 16, normal hearing)

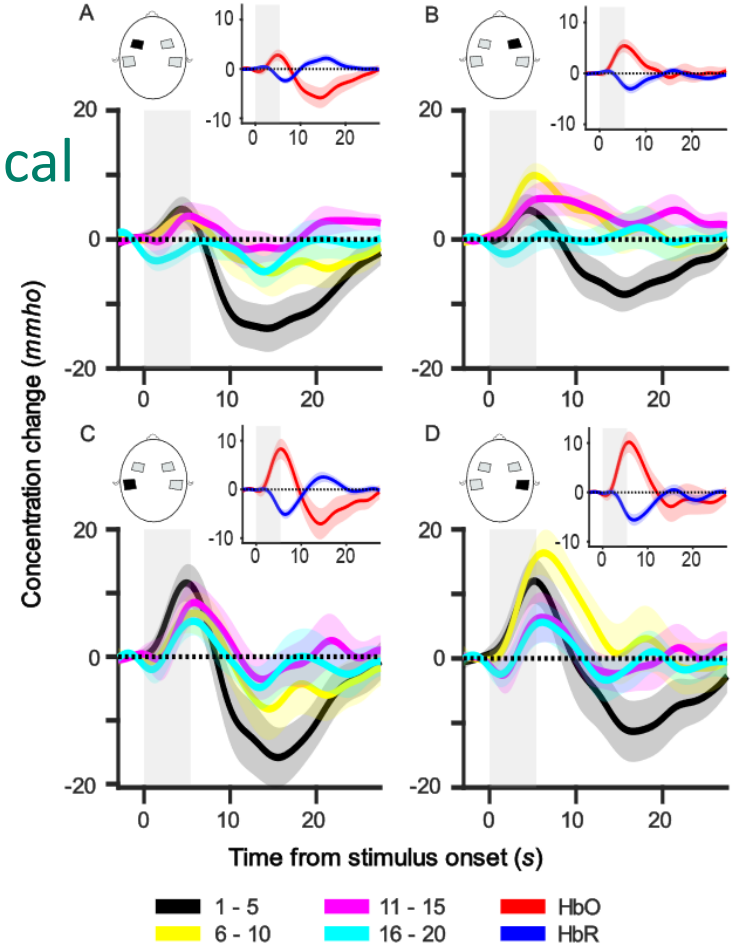
Grand averages 20 epochs per ROI



Expected canonical response

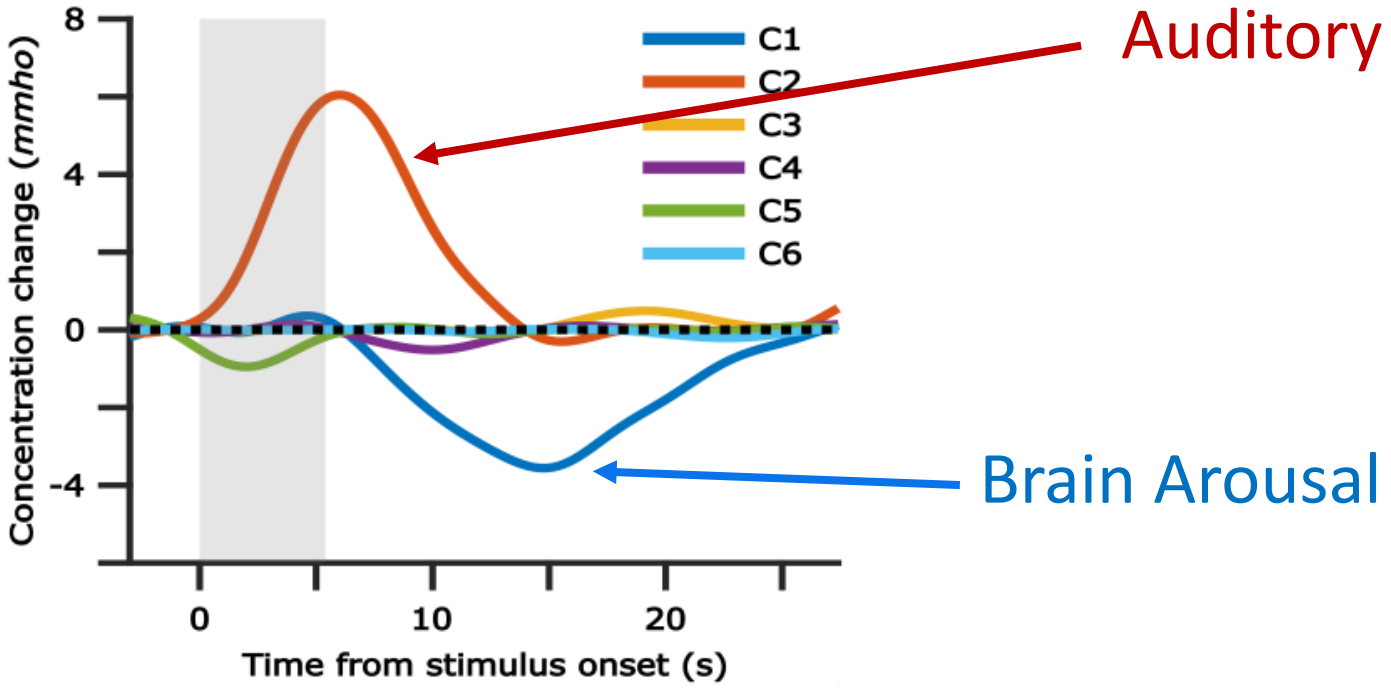
Unexpected negative component

Grand averages every 5 epochs per ROI



Two independent and concurrent responses to auditory stimuli (N = 16, normal hearing)

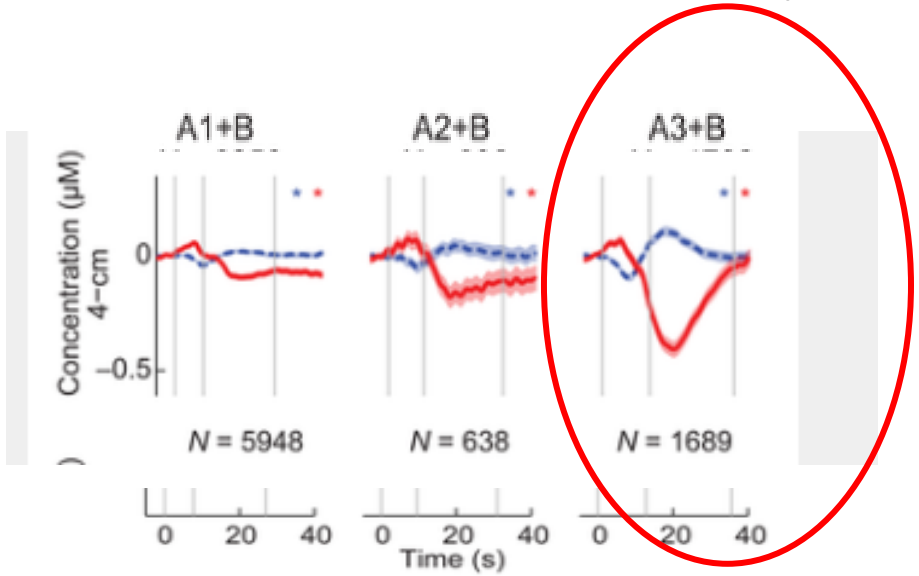
Grand average of reconstructed ICA components
(All epochs and channels used)



Why do we think it is a brain arousal response?

- McNamara et al J Appl Physiol (1998) (sleeping infants) tactile stimulus induced cortical arousal
- Cortical arousal defined as a sudden change in alpha activity
- Cortical arousal rapidly habituated with repeated stimuli

- Nasi et al, PLoS ONE 2012 (sleeping adults)
- Cyclic Alternating Patterns A-B occur in non-REM sleep.
- A1: Cluster of high amplitude alpha activity
- A2:transient high amplitude activity
- A3: transient high amplitude activity with desynchronization
- B: following A
- fNIRS epoched at starts of A phases



Näsi T, Virtanen J, Toppila J, Salmi T, Ilmoniemi RJ (2012) Cyclic Alternating Pattern Is Associated with Cerebral Hemodynamic Variation: A Near-Infrared Spectroscopy Study of Sleep in Healthy Humans. PLoS ONE 7(10): e46899. https://doi.org/10.1371/journal.pone.0046899

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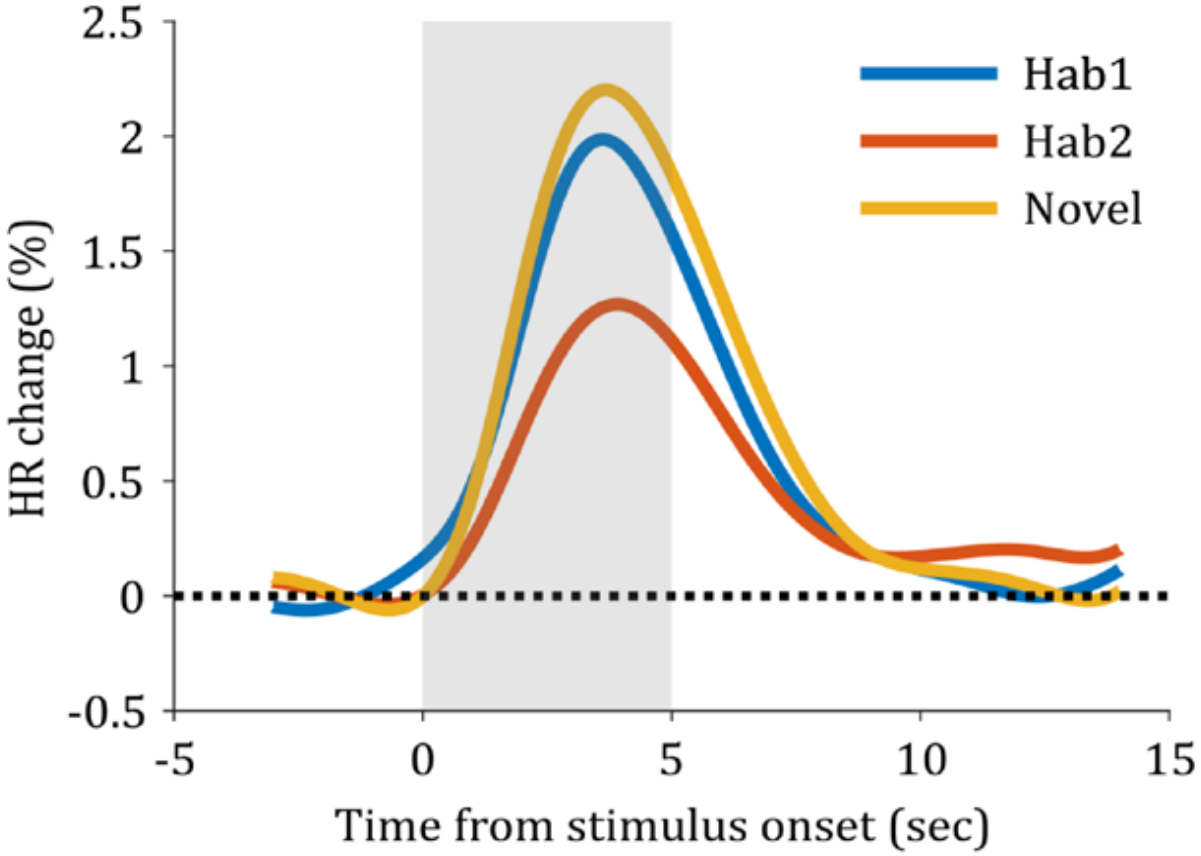
..and another physiological response to hearing sounds

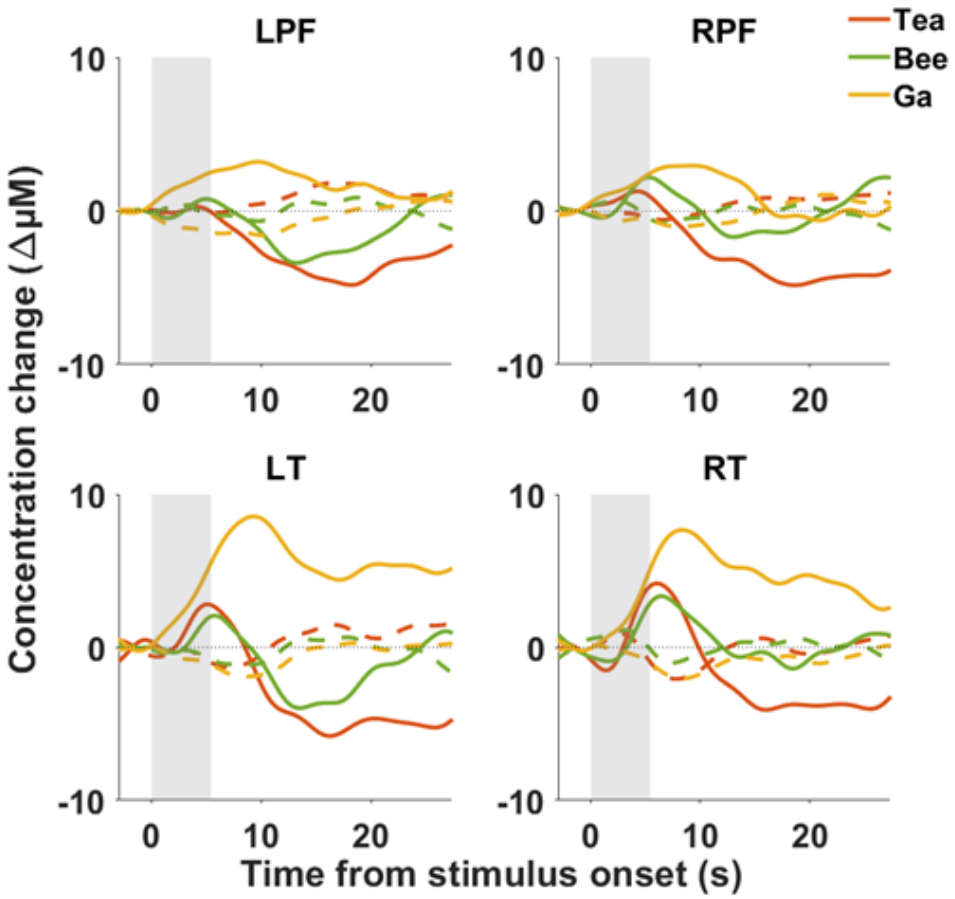


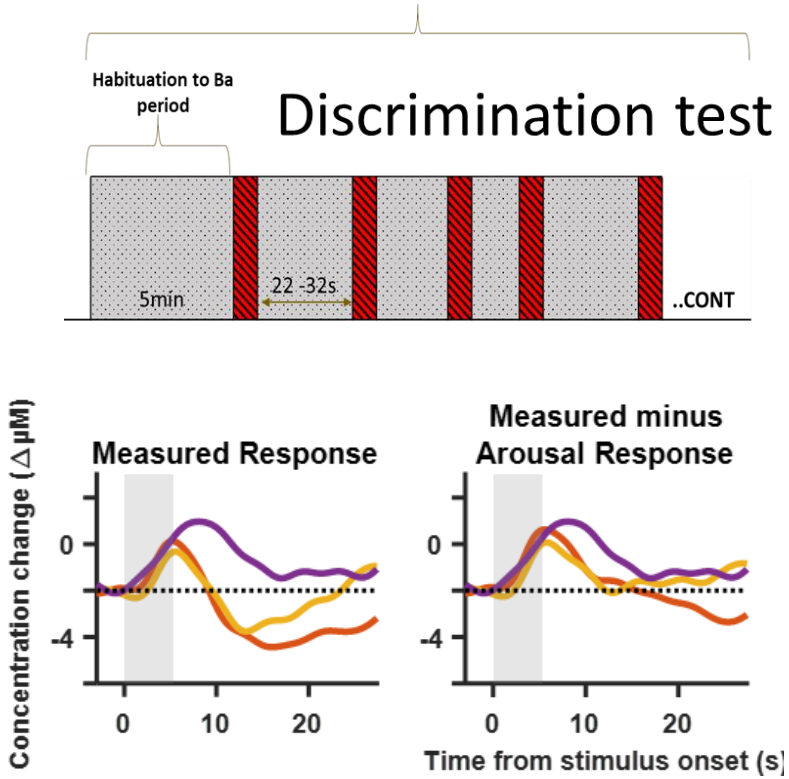
- Rapidly habituates (similarly to arousal response)
- Is only reliably measurable at higher intensities in normal hearing babies (>= 65 dBSPL)

Lee, O.W., et al.. (2023) “The use of heart rate responses extracted from functional near-infrared spectroscopy data as a measure of speech discrimination ability in sleeping infants,” Ear Hear 44(4):776-786

Discrimination response “Ba” versus “Tea”, “Bee”, and “Ga” at 65 dBSPL

Grand averages per ROI





- Same negative arousal component present
- Arousal **sensitive to degree of contrast**
- Positive acoustic component is broader and has longer peak latency than the detection response

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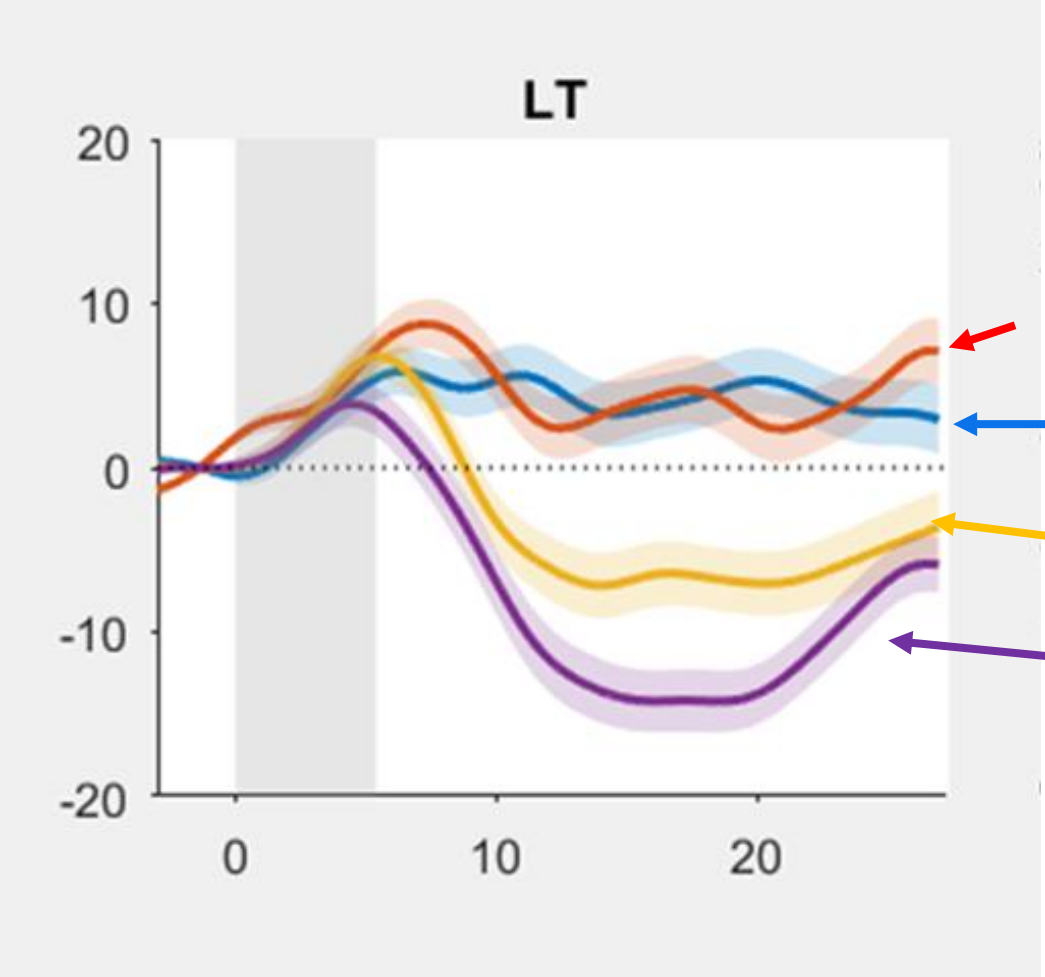
Effect of stimulus level on fNIRS response



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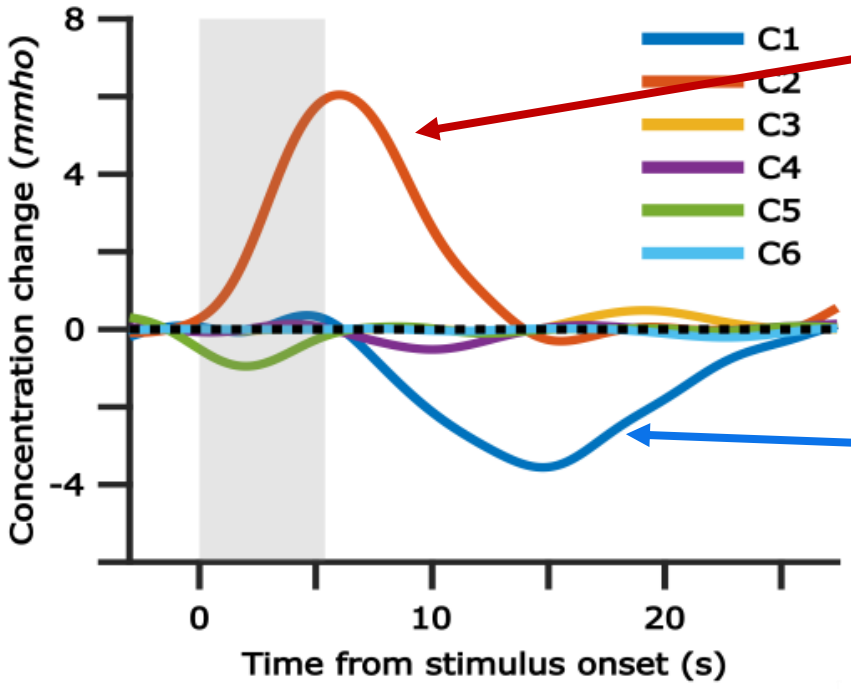
Summary of fNIRS response characteristics in sleeping infants



Auditory: latency and duration are affected by sound intensity or discrimination contrast

Brain Arousal: rapidly habituates
Size is affected by sound intensity and discrimination contrast

An automatic analysis method that is reliable and accurate in individual infants

- Needs to be able to automatically **detect non-stationary responses with differing morphology**
- A brief overview (patent protected)
  - Standard pre-processing steps to clean the signal and convert light intensities to HbO and HbR
  - A stochastic process captures the unique statistical properties of neural responses, illustrating neighborhood covariance relative to stimulus onset across a series of post-stimulus responses spanning the expected response lengths
  - Statistical significance is established by comparing the derived neural stochastic process against arbitrary baseline signals (from silence period or non-silence baseline).
  - To assess the probability of a false positive for that infant/ROI, control baseline signals are compared to each other using the same statistical process

Accuracy analysis in individual infants (normal hearing)

Specificity 95% (calculated across multiple control versus control tests in around 40 infants i.e. false positive estimate = 5%)

Secondary false positive check: control versus “0 dB SPL stimulus” 14 trials, no false positives

Sensitivity

Detection:

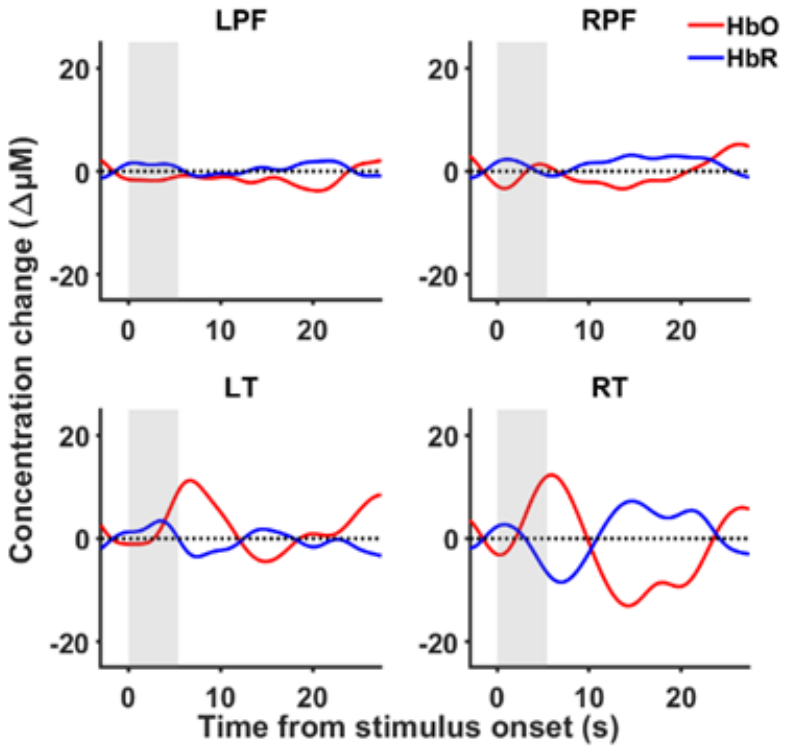
65 dB SPL 97-100% (28/29 infant tests)
Other levels 35 dB SPL to 90 dB SPL 100% (38 tests in all 5-8 tests per level)

Discrimination:

Ba/Tea 65 dBSPL 15/16 infants (94%)
Ba/Bee 65-75 dBSPL 30/33 infants (91%)
Ba/Bee 35-50 dBSPL 20/21 infants (95%)
Ba/Ga 65 dB SPL 14/16 infants (88%)

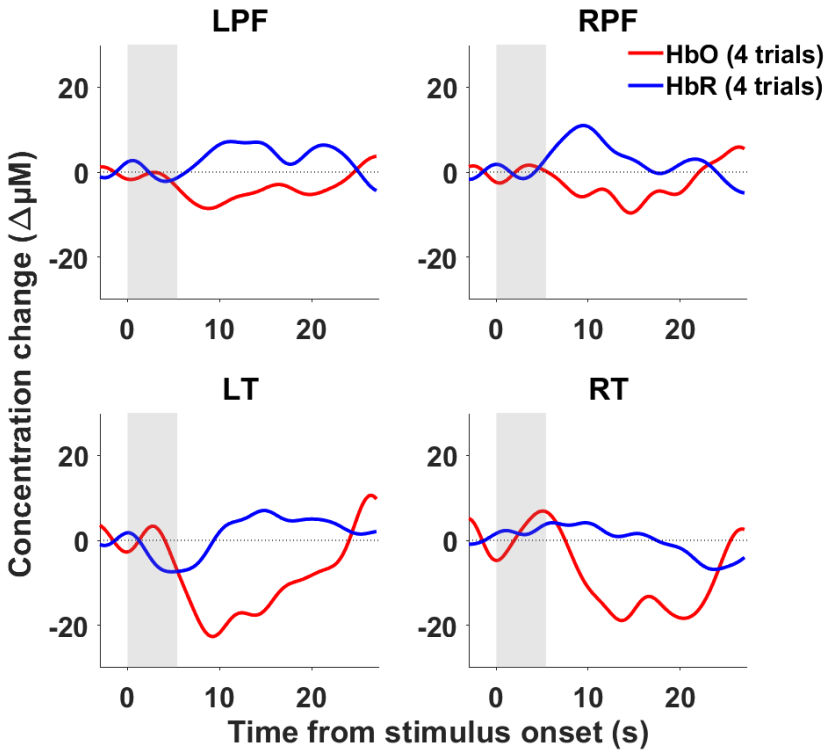
Example: infant (6m) with moderate hearing loss: Aided condition at 65 dBSPL: Detection responses

Average over 20 epochs



Algorithm says “Yes, detected”

Average over first 4 epochs



Note dominance of arousal response at start

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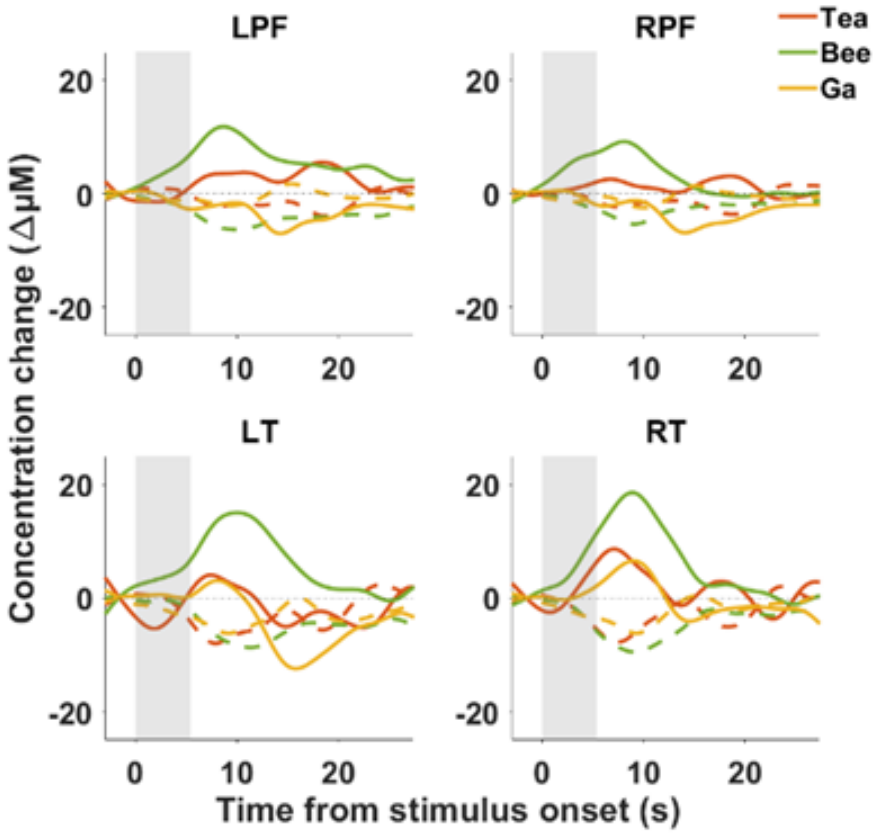
Example: infant (6m) with moderate hearing loss: Aided condition at 65 dBSPL: Discrimination responses

Average over 20 epochs

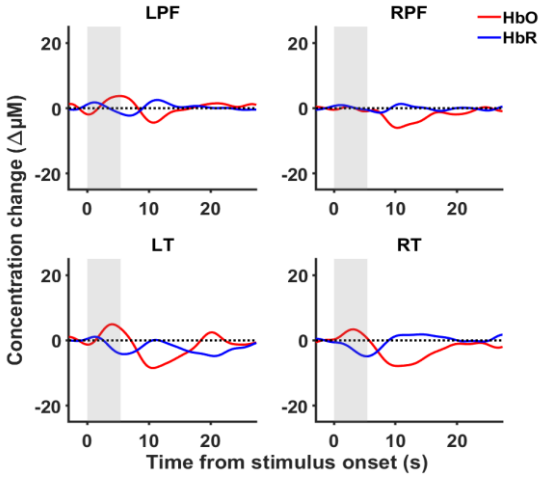


Note delayed positive peaks.

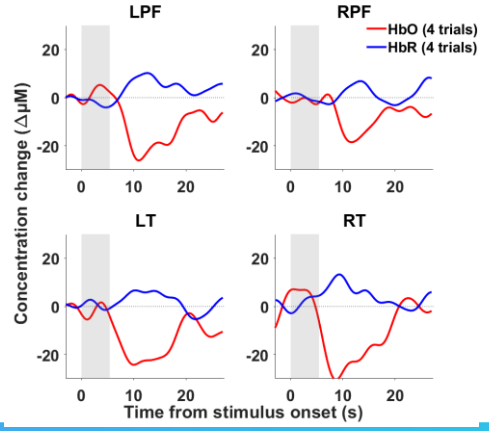
Algorithm confirms discrimination of all contrasts

Example: infant (bilateral severe/profound loss 5m and repeat 9m): aided condition at 65 dB SPL

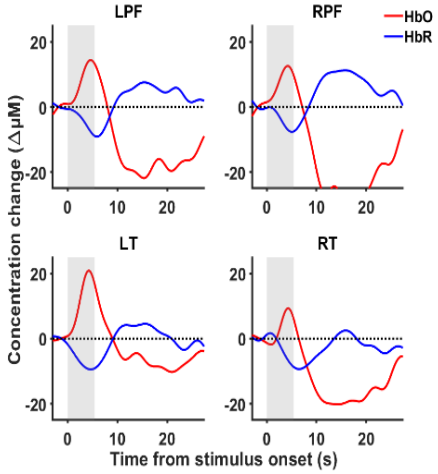
Detection responses at 5 months



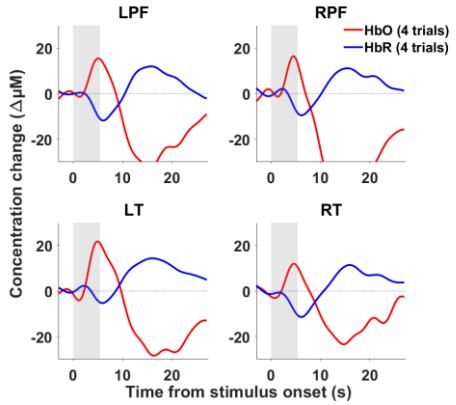
First 4 epochs



Detection responses at 9 months



First 4 epochs



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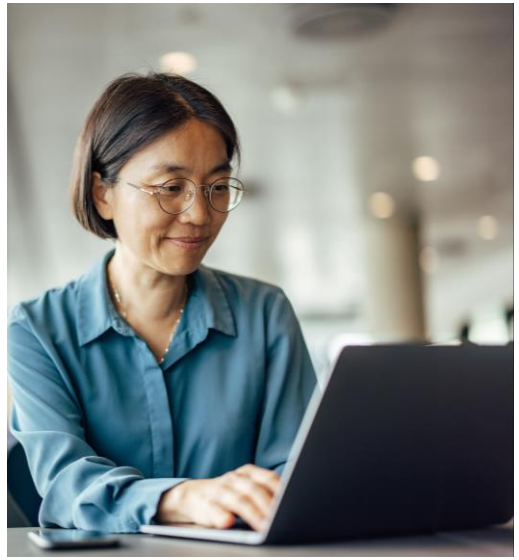
Developing a clinically easy system
…ready for clinical testing September 2023

Wireless connection



Automatic analysis and report

Baby-friendly head gear with fixed montage

Clinician friendly user interface

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