Characterizing the morphology of auditory evoked loudness dependent fNIRS responses in sleeping infants

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Introduction

Auditory-evoked fNIRS responses

- Studies have shown speech stimuli can evoke a functional near-infrared spectroscopy (fNIRS) response in infants.
- The responses vary in morphology depending on the experimental design and stimulus properties.

fNIRS response morphology

- Most studies reported the canonical shape haemodynamic response pattern (Fig 1).

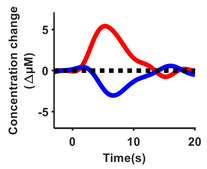

Figure 1: Example of the canonical haemodynamic response in infant fNIRS studies.

Our previous studies

- We have shown that fNIRS can measure speech detection and discrimination ability in sleeping infants using a habituation/dishabituation stimulus presentation paradigm [1] or a non-silence baseline protocol [2].

Research Question

Does the fNIRS response vary systematically with stimulus intensity?

Methods

Participants & Stimulus

We have included fNIRS responses from 7 sleeping infants with no known hearing loss in the analysis.

- Participants aged between 3 - 14 months
- The stimulus was 10 /Ba/ speech tokens concatenated to a 5.4 s stimulus block.
- Speech stimulus block were presented at different intensity levels (45, 60, 75 and 90 dB SPL) in an pseudorandomized manner.

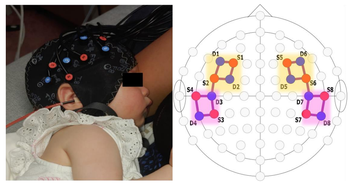

Figure 2: A sleeping infant with the fNIRS cap *(left)*. The fNIRS recording montage *(right)*. FNIRS sources are marked in red circles, detectors are marked in blue circles. The regions of interests are marked in shaded areas where yellow represents pre-frontal region and violet represents temporal region.

Data pre-processing

- Data were analysed using the NIRS Brain AnalyzIR toolbox and custom script.
- Data were converted to optical density and haemoglobin change.
- Motion artefacts were corrected using the TDDR function.

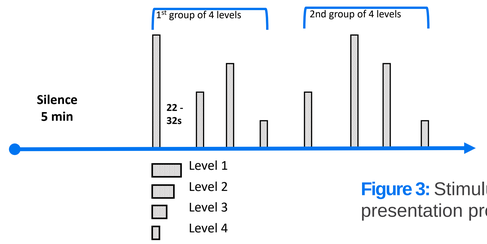

Figure 3: Stimulus presentation protocol

- The data were band pass filtered between 0.01 – 0.25 Hz.
- Channels with SCI threshold <0.8 were discarded.
- The data were epoched between -3 s and 27 s from stimulus onset, and baseline corrected to the average of –3 to 0 s.

Results

Group-level speech detection responses for each sound intensity level were identified in all four regions of interest (Fig. 4).

For each intensity level:

- One canonical-like positive response peak around 5-6 s.
- One wide negative trough peak around 10-15 s.
- The amplitudes and latencies of These responses varied with different stimulus intensity levels.

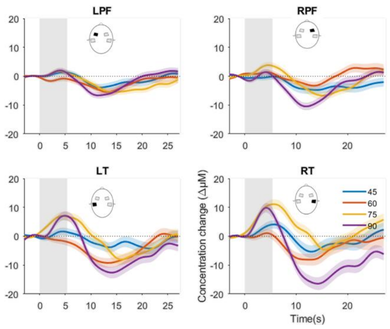

Figure 4: Group average HbO responses for each intensity level per ROI. LPF = left pre-frontal, LT = left temporal, RPF = right pre-frontal, and RT = right temporal. Shaded region = one SEM.

Independent component extraction using principal component analysis (PCA) and independent component analysis (ICA)

- We proposed a method to extract the independent components in the fNIRS responses (Fig. 5).
- We hypothesized that two extracted independent components consist of a positive component and a negative component, which confirms our previously discovered two independent response mechanisms [2].

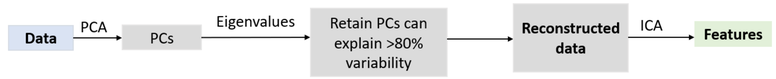

Figure 5: Schematic diagram of the independent component extraction method.

- Fig 6 shows the average independent components.
- Fig 7 shows the reconstructed fNIRS responses using the extracted independent components.

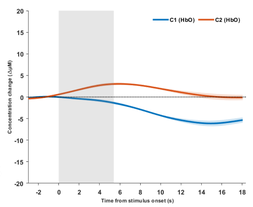

Figure 6: Group level ICA decomposition. Two independent components extracted from fNIRS responses.

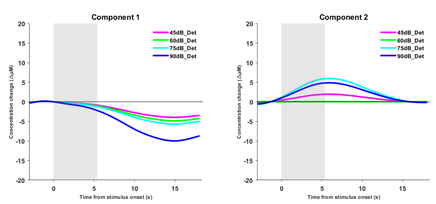

Figure 7: The reconstructed two components for each intensity level.

Discussion

- To test the stability of an independent component, we performed 20 repetitions of randomly initialized ICA on our data.
- The results confirms our hypothesis on the two independent response mechanisms.
- We observed that the amplitudes of the reconstructed fNIRS responses vary with different stimulus intensity levels.

Conclusion

We proposed a method to extract the independent components in the fNIRS responses based on PCA and ICA. We hypothesize that two extracted independent components consist of a positive component and a negative component. The extracted components are valuable features that can be used for objectively assessing hearing levels in sleeping infants.

[1] Mao, D., Wunderlich, J., Savkovic, B., Jeffreys, E., Nicholls, N., Lee, O.W., Eager, M., McKay, C.M. 2021. Speech token detection and discrimination in individual infants using functional near-infrared spectroscopy. Sci Rep 11, 24006.

[2] Lee, O.W., Mao, D., Wunderlich, J., Balasubramanian, G., Haneman, M., Korneev, M., McKay, C.M. [Manuscript submitted for publication]. Two independent response mechanisms to auditory stimuli measured with fNIRS in sleeping infants. doi: 10.21203/rs.3.rs-2493723/v1

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