Brain activation patterns in newborns: The influence of prenatal exposure to a foreign language

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INTRODUCTION

THE FŒTUS

- Perceives and processes sounds from mid-pregnancy, despite in utero sound distortion (attenuation of high frequencies) [1]
- Cardiac deceleration when listening to a familiar story [2]

THE NEWBORN

- Left-hemispheric dominance brain response to familiar sounds (native language, mother's voice) [3]
- Results are inconsistent regarding cerebral response to native and unfamiliar languages (left vs. right dominance [4], increase vs. decrease [5], no difference [6])
- Infants show a cardiac deceleration and a large brain mismatch response to sounds that were repeatedly exposed in utero [7-9]

OBJECTIVE Characterize the influence of prenatal exposure to a new language on the newborn brain response in comparison to its native language and an unfamiliar language.

METHODOLOGY

N = 59 healthy newborns from French unilingual families
Mean age at NIRS recording: 30 ± 13 h
*No significant differences for sociodemographic, clinical factors and prenatal exposure

		Prenatal exposure to	
	Controls	**German**	**Hebrew**
N (♀)	21 (53%)	20 (55%)	18 (50%)
Gestational age (weeks:days)	40:0 ± 1:0	39:5 ± 0:5	39:5 ± 1:0
Weight (kg)	3.5 ± 0.5	3.5 ± 0.6	3.4 ± 0.4
APGAR (10m)	9 ± 0.2	9 ± 0.5	9 ± 0.2
Maternal education (% university degree)	75%	89%	93%
Number of prenatal exposure sessions	-	47 ± 18	53 ± 17

PRENATAL EXPERIMENTAL CONDITION

Linguistic **prenatal exposure** to a children's story in the **native** (*French*) and one **foreign** language (*German* or *Hebrew*)

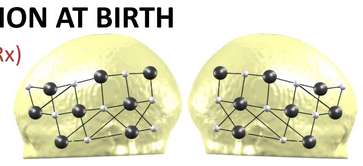
- 2 x everyday from 35th week of pregnancy until birth
- Through headphones places on the abdomen
- Those foreign languages were chosen as their rhythmic and linguistic classes differ from the ones of the native language.

NEAR-INFRARED SPECTROSCOPY (NIRS)

Indirect measurement of neural activity through neurovascular coupling → Concentration changes of oxygenated (HbO) and deoxygenated (HbR) hemoglobin (ΔConc). [10-11]

DATA ACQUISITION AT BIRTH

NIRScout System (NIRx)



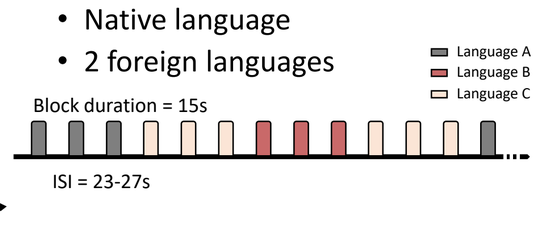
- 32 sources (760nm and 850 nm) and 16 detectors
- Each source-detector pairing represents a channel.

TASK PARADIGM

3 CONDITIONS x 18 BLOCKS

Passive listening of the same children's story

- Native language
- 2 foreign languages

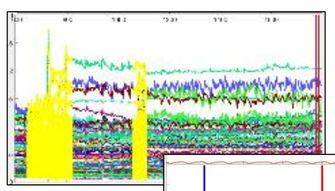


Block duration = 15s

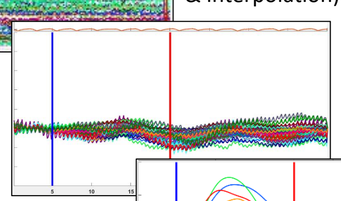
ISI = 23-27s

DATA ANALYSIS

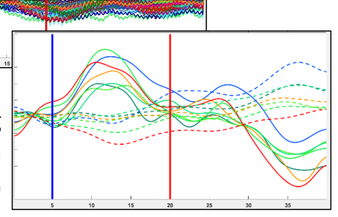
Preprocessing steps using the LIONnirs toolbox [12] in SPM (Matlab R2019b)



Correction of motion artefacts (target decomposition [13] & interpolation)



Segmentation
Baseline normalization



0.2 Hz low-pass filtering
ΔConc HbO/HbR calculation (modified Beer-Lambert's law)

Average ΔConc across blocks (for participant x condition)

Extraction of the mean Δconc in two 5-sec time windows
7 to 12s after stimulus onset: **around the first peak**
12 to 17s after stimulus onset : **sustained response**

STATISTICAL ANALYSES

(experimental newborns)

1. **Repeated-measure analysis of variance** on HbO ΔConc across conditions and time windows

Planned contrasts: Fam compared to each condition

Native vs. **Familiar** vs. **Unfamiliar**

According to the prenatal exposure (either German or Hebrew)

2. **Simple regression** on the HbO Δconc relative difference of Familiar condition with other conditions

Amount of prenatal exposure → $\frac{\textbf{Fam} - (\text{Nat} \mid \text{Unf})}{\textbf{Fam}}$

PRELIMINARY RESULTS

Results are reported from N = 36 newborns that all underwent the prenatal exposure
(N=2 excluded due to poor quality of data)

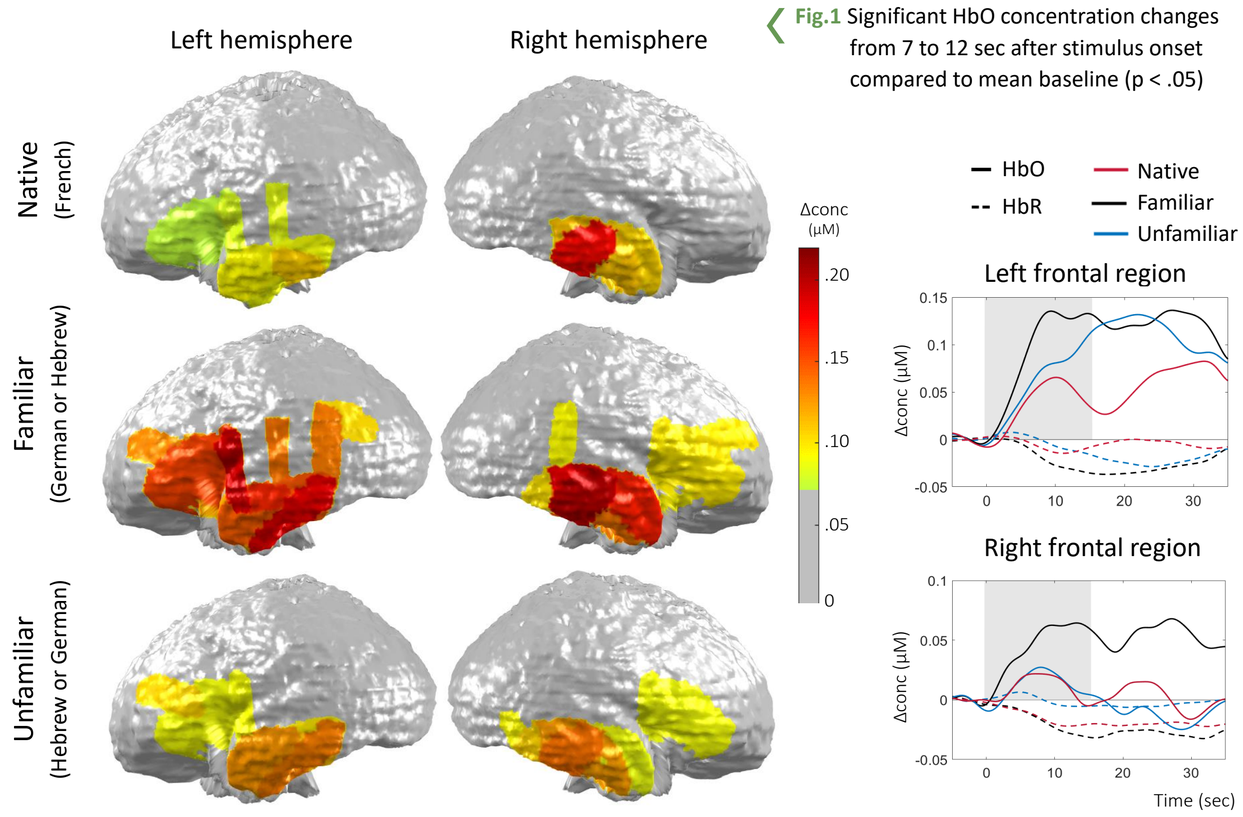


Fig.1 Significant HbO concentration changes from 7 to 12 sec after stimulus onset compared to mean baseline ($p < .05$)

1. Marginal differences of mean activation to the stories <u>between conditions</u> both at the first peak and in the sustained response :

- **Medial region of the left frontal lobe** $F(2,70)=2,85$, $p=.064$
  → Familiar > Native ($p=.028$)
- **Medial and inferior regions of the right frontal lobe** $F(2,70)=2.48$, $p=.091$ $F(2,70)=2,81$, $p=.066$
  → Familiar > Native ($p<.036$)

2. The <u>amount of prenatal exposure</u> predicts the relative difference between:

Familiar and Unfamiliar conditions

- Left frontal region $\beta = 0.94$, $p = .041$
- Left superior temporal region $\beta = 0.14$, $p = .026$
- Right posterior temporal region $\beta = 0.49$, $p = .025$
- Right anterior temporal region $\beta = -0.11$, $p = .053$

Familiar and Native conditions

- Left parieto-temporal junction region $\beta = 0.19$, $p = .031$
- Right posterior temporal region $\beta = 0.19$, $p = .014$

DISCUSSION

Bilateral temporal activations in all conditions

- Concordant with the newborn literature in fNIRS. [14]
- Would reflect the auditory processing specific to any language stimulus. [6-10, 15]

Stronger activation for the prenatal familiar language in **bilateral frontal regions compared to the native language**, but not the unfamiliar language.

- Cortical frontal regions are more strongly recruited when processing familiar but still novel language (i.e. prenatal experimental) compared to excessively familiar language (i.e. native).
- The newborn's brain appears to recognize linguistic stimuli that were exposed in utero.

A larger **amount of prenatal exposure** to the familiar foreign language predicted a larger activation compared to other conditions (i.e. positive relative difference) in various regions known to be associated with language networks. [14]

- A potential avenue of research is to explore language pre-networks with functional connectivity analysis and how it is modulated with prenatal exposure. [17]

Important **inter- and intra-individual variability** regarding the response pattern (i.e. increase vs. decrease of Δ Conc, across blocks and participants) [16]

- Random effect from participants and additional predictors could be modelled using mixed-effects model.

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