Average daily speech exposure for fetuses and preterm infants

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Introduction

The quality and quantity of speech and language exposure during early childhood is believed to have an impact on language ability during later childhood. The human auditory nervous system comes "online" *in utero,* at least as early as 23 weeks' gestation. Intrauterine fetal experience with extrauterine sounds during the last trimester of gestation is sufficient to modify auditory brain development and neural responses to speech. How and whether fetal exposure to speech affects later childhood language development remain open and difficult questions.

To begin to address these questions, we aimed to quantify speech exposure for typically developing fetuses and preterm infants. We collected and analyzed auditory exposure data for: (1) sounds generated in the extrauterine environment for fetuses, and (2) sounds generated in the neonatal intensive care unit (NICU) for preterm infants. We then related our exposure data to auditory neural development in infancy.

Fetal hearing

Humans are altricial mammals with precocial hearing. Fetuses display reliable behavioral responses to extrauterine acoustic stimuli as early as 23 weeks' gestation (Figure 1). What are fetuses hearing?

The prenatal acoustic environment is dominated by mother's cardiovascular, vocal, and digestive sounds transmitted *via* amniotic fluid. Also present are extrauterine vocalizations, music, and other sounds that impinge on the abdomen of the mother and exceed the intrauterine noise floor. Full-term newborns display behavioral and neurophysiological responses that distinguish between acoustic stimuli to which they were exposed *in utero* and novel stimuli. Prenatal learning has been demonstrated for mother's voice, mother's native language, frequently heard speech passages, individual phonemes, speech prosodic features, and music.

Fetal hearing (continued)

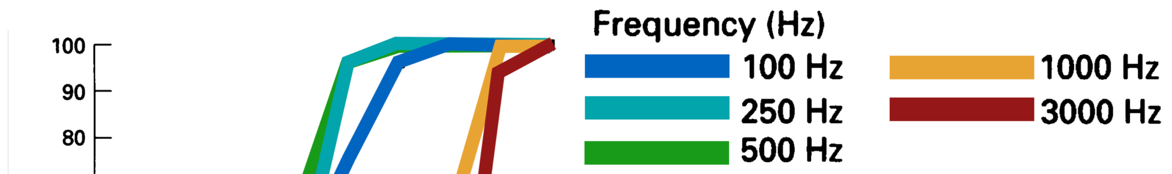

Figure 1. Development of frequency sensitivity for fetuses. Behavioral responses to extrauterine pure tones at low frequencies precede those to higher frequencies (Hepper and Shahidullah, 1994).

Prenatal hearing and auditory learning is facilitated by an auditory neural pathway mature enough to permit cochlear input to reach at least auditory cortical regions.

The abdomen wall provides some attenuation of extrauterine sound into the intrauterine environment, but perhaps not as much as is generally believed. Maximum attenuation is ≤ ~15 dB at the highest frequencies (Figure 2). Extrauterine speech is audible and fairly intelligible.

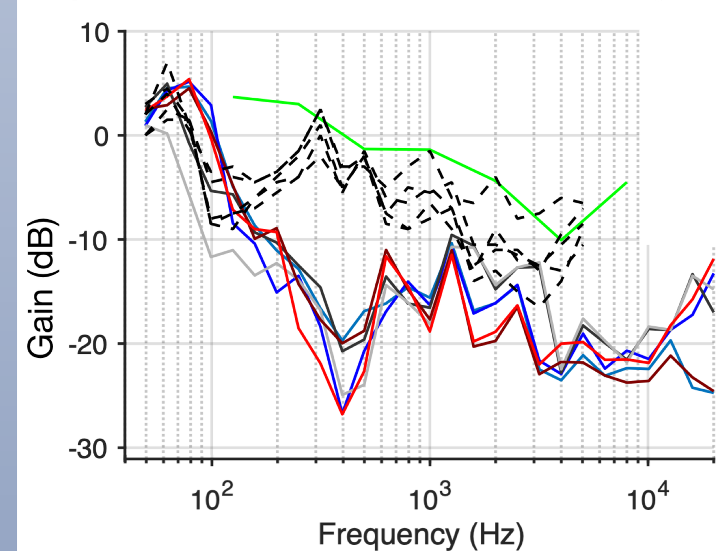

Figure 2. Transfer functions for a pregnant sheep abdomen (dashed; Peters et al, 1993), a pregnant human abdomen (green; Richards et al 1992), and incubator walls (other colors; Monson et al, 2020).

Method

<u>Recordings</u>:

- LENA audio recorders
- 24-hr audio recordings, 16-kHz sampling rate
- Automated classification of durations of different sound categories: speech, electronic sounds, noise, silence

<u>Fetal group</u>:

- 21 healthy pregnant women
- Between 20 and 32 weeks pregnant at time of enrollment
- Device worn in LENA-compliant pouch around the neck
- Recordings made 2x per week until delivery

Method (continued)

<u>Very preterm (VPT) group</u>:

- 20 very preterm (VPT) infants born ≤32 weeks' gestation
- Device placed next to infant (in incubator/crib and when held) 3x per week during NICU stay

<u>Auditory brainstem responses (ABR)</u>:

- 11 full-term infants (fetal group) returned at age 3 months (52 weeks postmenstrual age)
- Click ABRs @ 80 dBnHL; tone burst ABRs at 0.5, 1, 2, 4, 6, and 8 kHz (data not shown)

Results

- >11,000 hrs of fetal data; >10,000 hrs of VPT data
- Average daily speech exposure:
  - Fetal: 4.7 ±0.9 hrs; range 3 – 6.1 hrs
  - VPT: 3.5 ±1.3 hrs; range 1.8 – 6.4 hrs

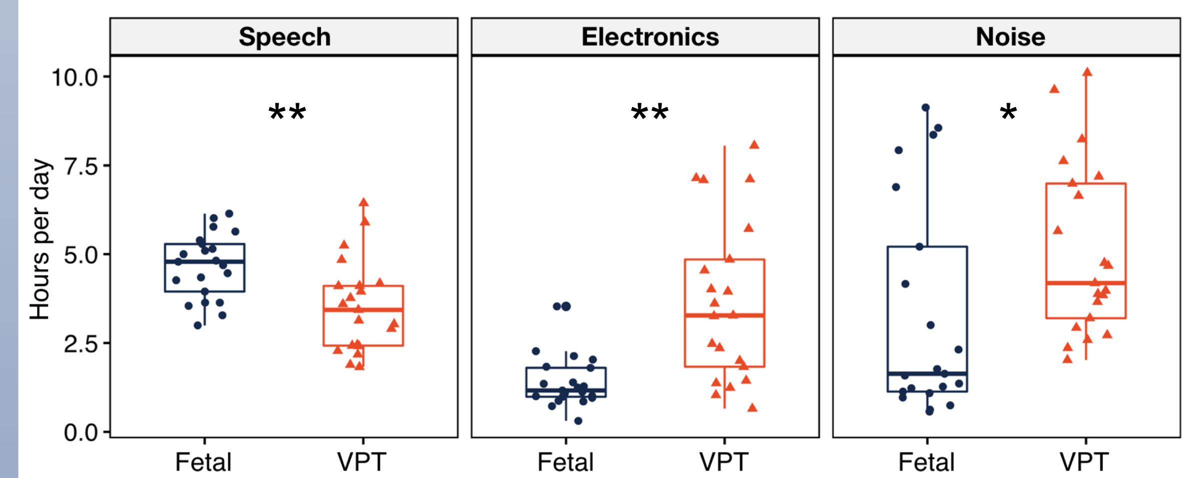

Figure 3. Average daily exposures for each group for speech, electronic sounds, and airborne noise. *$p<0.05$, **$p<0.005$

- Significant group differences in exposure to speech, electronic sounds, and airborne noise (Figure 3)
- Circadian pattern apparent for fetal exposures, but not VPT exposures (Figure 4)
- Average daily silence for VPT group: 13 ± 3.9 hrs
- Average daily extra-uterine silence for fetal group: 11.5 ± 3.6 hrs

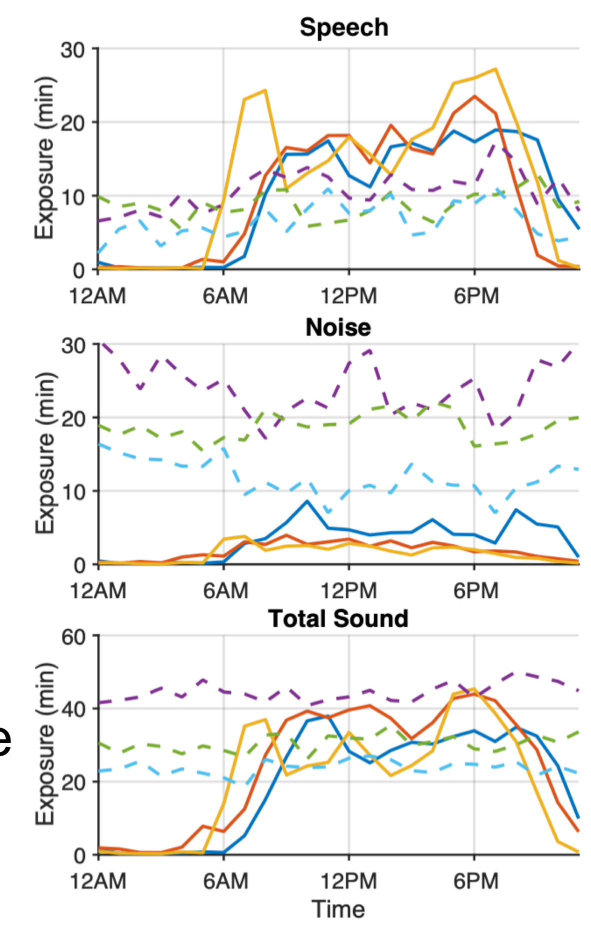

Figure 4. Average hour-by-hour exposures for 3 fetuses (solid) and 3 VPT infants (dashed).

Results (continued)

- Non-significant trend (*n*=11) for relationship between higher prenatal daily speech exposure and lower ABR latencies

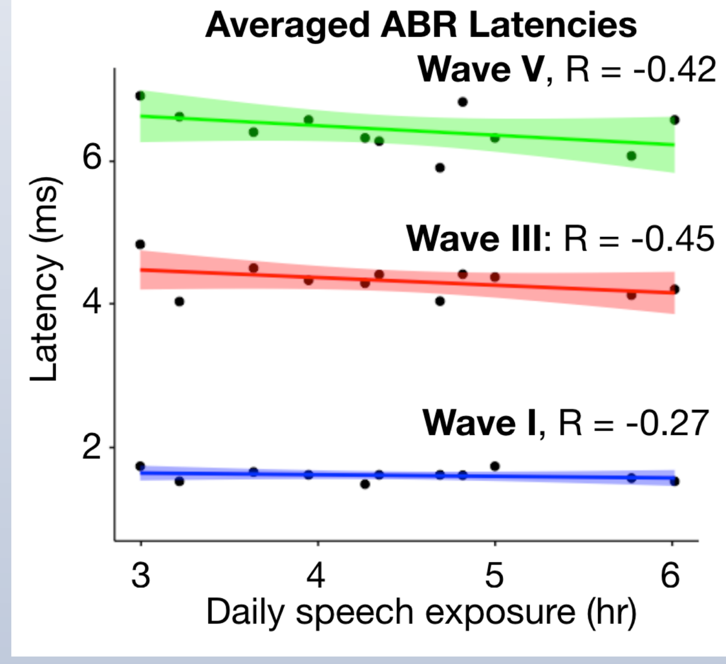

Figure 5. Left-right averaged click ABR latencies as a function of average daily prenatal speech exposure for the fetal group.

Conclusions

- Daily speech exposure for typically developing fetuses is 4.7 hrs, but 3.5 hrs for VPT infants, indicating a 25% decrease
- Substantial within- and between-subject variability: Some full-term newborns are born with only 50% of the speech exposure of their peers
- Fetuses, but not VPT infants, experience circadian patterns of extrauterine exposures
- Limitations: What fetus actually hears is uncertain due to intrauterine noise floor, auditory pathway development, and altered (fluid) acoustic pathways to fetal inner ear
- Data collection is ongoing, including longitudinal follow-up

References

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