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What is the effect of sensory impairment on language processing?

Aging alters the perception and physiological representation of frequency.

Christopher G. Clinard, Kelly L. Tremblay, Ananthanarayan R. Krishnan
2009

Speech as a complex signal

The speech signal is composed of many varying acoustic cues in which speech sounds are encoded.

"I can hear you but I can't understand you."

Hearing difficulties in old age are thought to arise from reduced sensitivity to variation in frequency and timing cues.

Previous studies in auditory perception

Perceptual studies in temporal resolution

- Gap detection thresholds (Schneider and Hamstra 1999)
- Duration discrimination (Gordon-Salant and Fitzgibbons 1999)
- VOT discrimination (Tremblay et al. 2003)

Physiological studies in temporal resolution

- Silent gaps in noise (Poth et al. 2001)
- Amplitude-modulated tones (Leigh-Paffenroth and Fowler 2006)

Previous studies in auditory perception

Frequency discrimination and frequency modulation detection

- Age-related deficits are more common in lower frequencies (500Hz and 1000Hz) than in higher frequencies (2000Hz and 4000Hz)
  - Frequencies below 1000Hz are more strongly associated with phase-locking, which seems to decline with age

Measures of frequency

Frequency discrimination limens (FDLs)

- Age-related deficits are consistently more prevalent at lower frequencies

Auditory evoked potentials (AEPs)

- Age-related differences are found to affect the amplitude and latency of the P1-N1-P2 complex when evoked by frequency changes

Frequency following responses (FFRs)

- A steady-state AEP evoked by low-frequency stimuli, which are dependent on phase-locked activity in the auditory brainstem

Experimental set-up

Subjects

- 32 subjects in behavioural condition and 28 in physiological condition
- All had clinically normal hearing sensitivity
- Ages 22 to 77 with 5 subjects per age group

Stimuli

- 500ms long tonebursts
- Delivered through a magnetically shielded earphone

Behavioural condition

Frequency discrimination

- Tested separately at 500Hz and 1000Hz
- Each test frequency was part of a two-alternative forced choice procedure

  Tone 1 → test frequency

  Tone 2 → lower than test frequency

- Tone pairs were played in a random order
- Subjects had to select the button with the highest frequency tone
- Feedback given - correct button lit up

Physiological condition

Frequency following responses

- Taken at six frequencies: 463, 498, 500, 925, 998, 1000Hz

FFR data was analysed offline in two ways:

  - Amplitude: averaged magnitude of the neural response
  - Phase Coherence: degree of phase-locking to stimulus frequency

- Analyses were put through a fast Fourier transform and used to verify response presence

Results: frequency discrimination

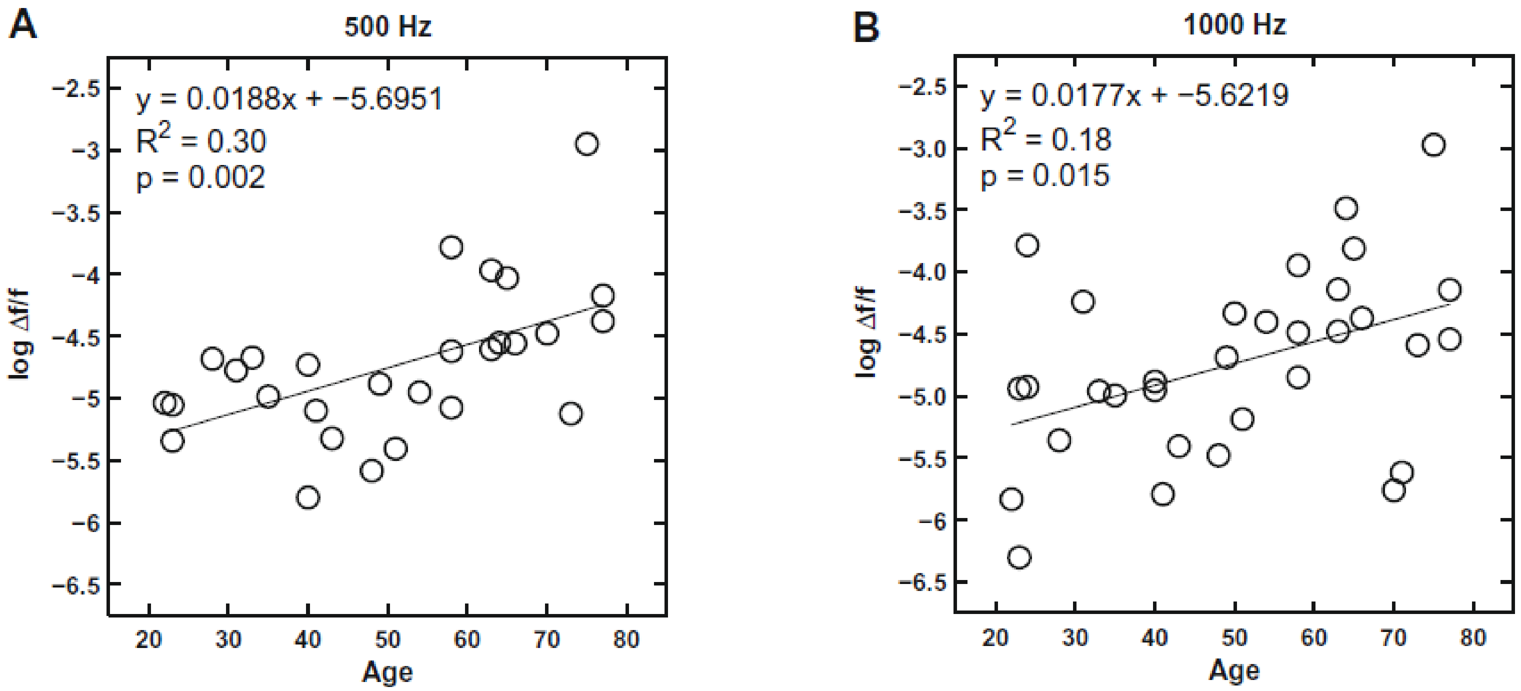

Fig. 2. Log-transformed FDLs as a function of age for 500 Hz (A) and 1000 Hz (B). The linear fit, regression formula, and *p*-value are shown in each panel. FDLs became significantly poorer as age increased.

Results: frequency-following response

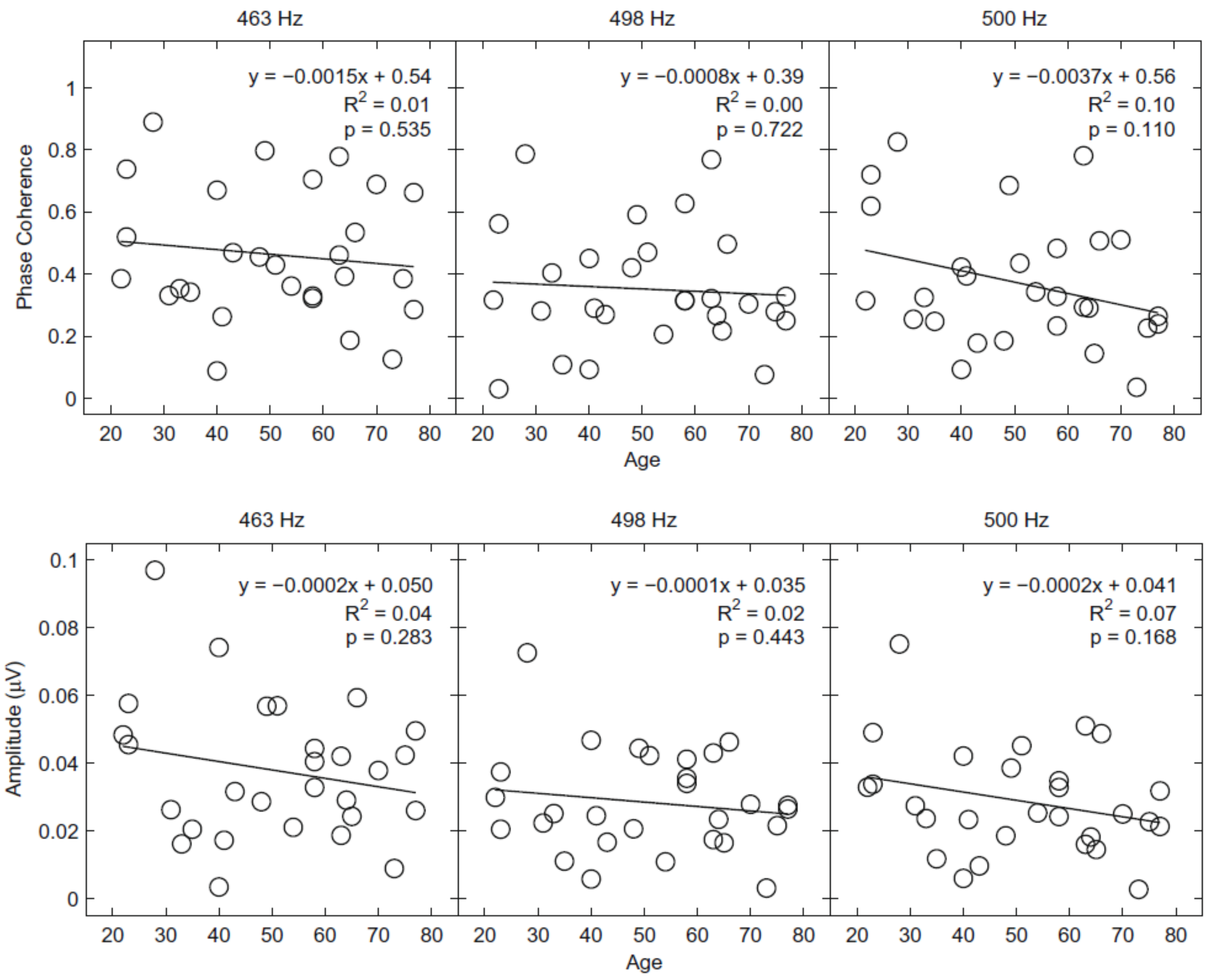

Fig. 3. FFR data from 463, 498, and 500-Hz conditions. PC (top row) and amplitude (bottom row) are plotted as a function of age. The linear fit, regression formula, and *p*-value are shown in each panel.

Results: frequency-following response

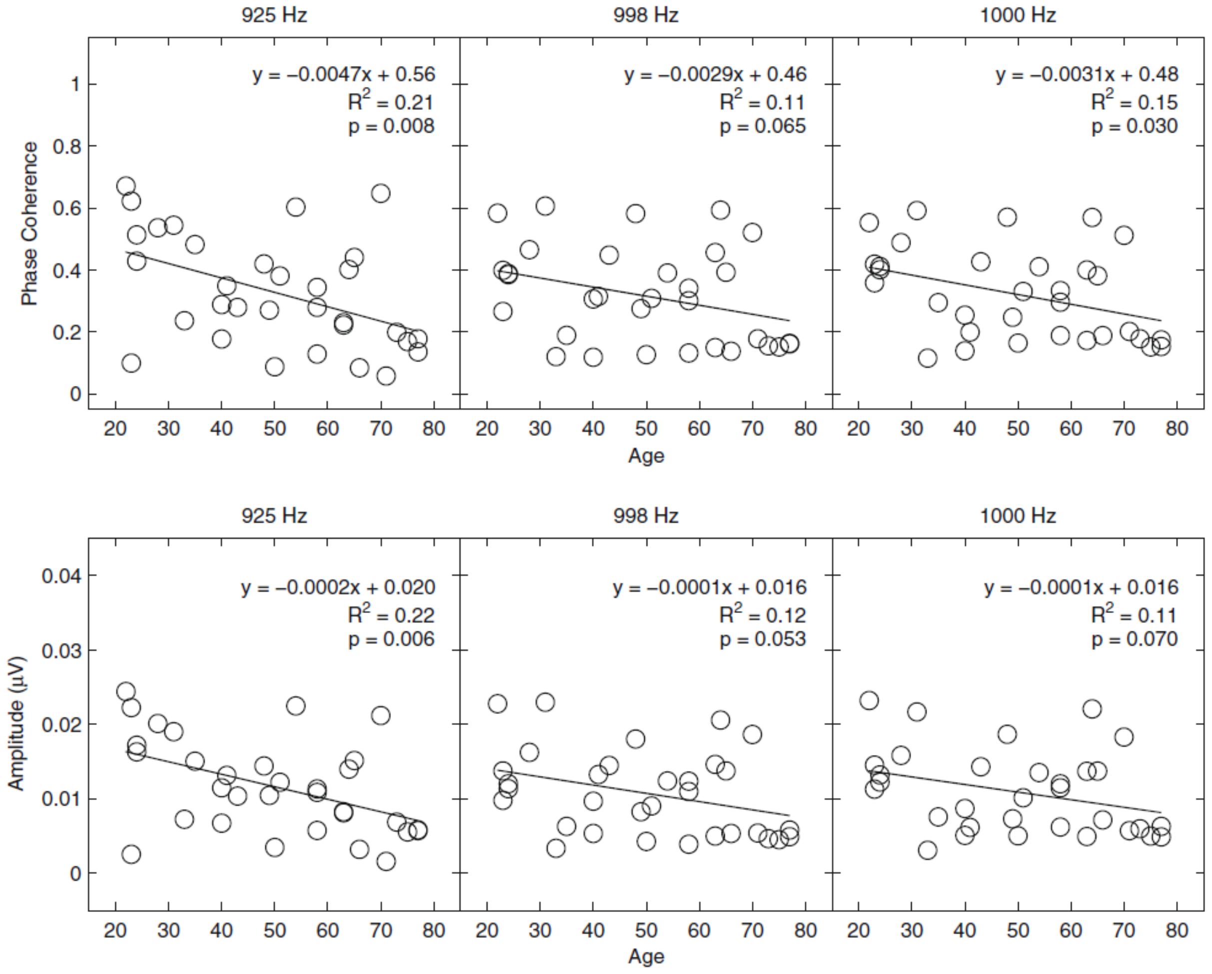

Fig. 4. FFR data from 925, 998, and 1000-Hz conditions. PC (top row) and amplitude (bottom row) are plotted as a function of age. The linear fit, regression formula, and *p*-value are shown in each panel. FFR measures significantly decreased as age increased.

Results: physiology and perception

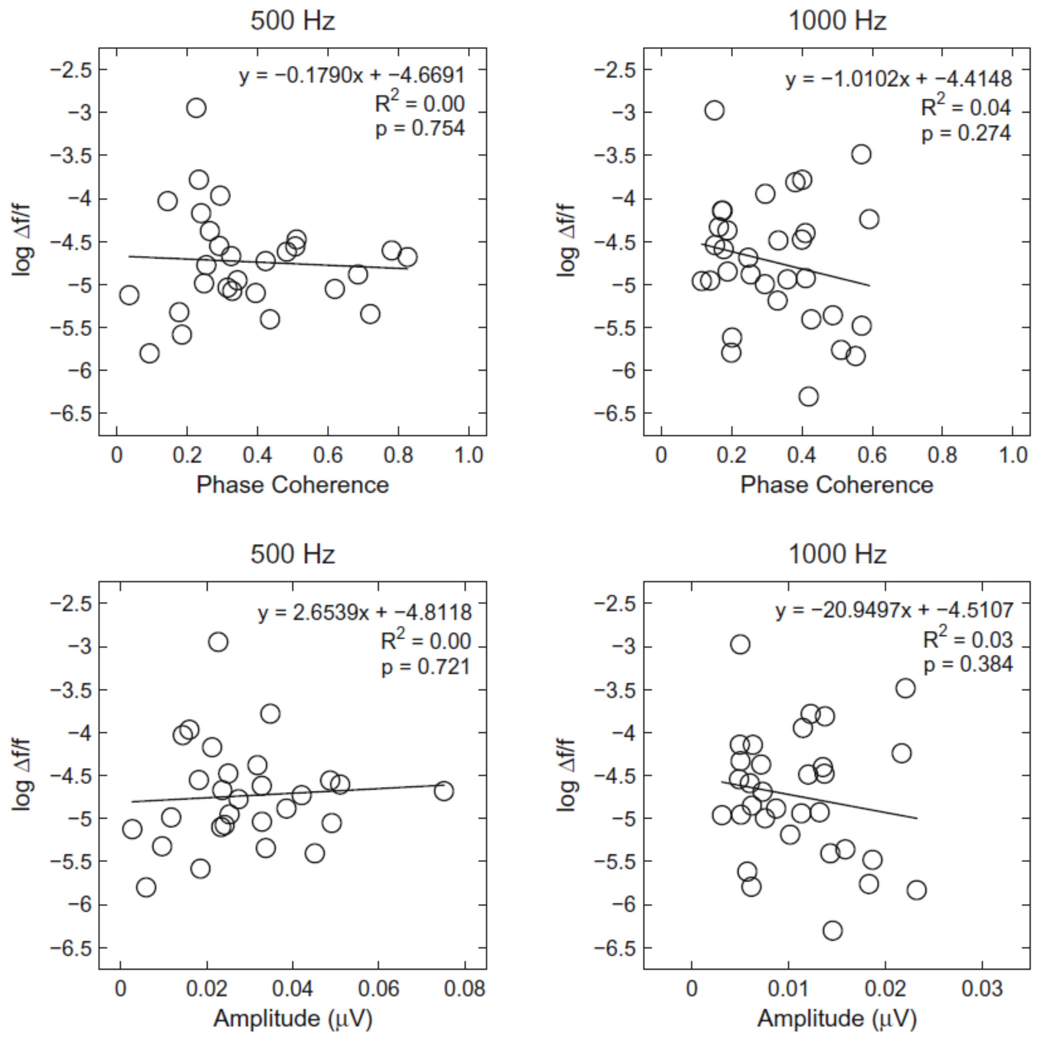

Fig. 5. Bivariate plots of FFR PC or amplitude and log-transformed FDLs. FFR data were not significantly predictive of FDLs.

Findings

The ability to discriminate pitch becomes worse with age

Neural representations of pitch become weaker with age

- Neural responses to frequency were poorer for stimuli around 1000Hz than for stimuli at 500Hz

The neural representation of frequency (FFR) was not predictive of frequency perception (FDL).

- There are other neural activities and pathways associated with frequency discrimination

Implications

What is the effect of reduced frequency perception on language processing?

Leads to difficulty in identifying spectral cues such as:

- Speech segments
  - Particularly vowels, which are periodic and distinguished by formant frequencies
- Prosody
  - Whether an utterance is a question or statement
  - The emotion of a speaker

Discussion

How might non-sensory processes affect frequency perception?

- Cognitive processes e.g. attention, memory, motivation
- Musical training
- Any others?

How might the stimulus context affect processing?

- A pair of stimuli were present in the frequency discrimination task
- A single stimulus was presented in the FFR procedure