Temporal processing as a function of pulse rate and age: Behavior and electrophysiology

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INTRODUCTION

- The auditory system is rate limited, which affects a listener's ability to process rapid temporal information.
- Previous research has also demonstrated that temporal processing slows with age (e.g., Gordon Salant et al., 2006).
- Younger normal-hearing (YNH) listeners' ability to encode temporal information in bandlimited acoustical pulse trains decreases as pulse rates increase beyond a few hundred pulses per second (pps) [Carlyon et al., 2008].
- However, previous research has yet to investigate rate limitations in older NH listeners.

- **The purpose of this experiment was to investigate if increased pulse rate would affect temporal rate discrimination, behaviorally and electrophysiologically, due to age-related temporal processing deficits.**

LISTENERS

- YNH: <45 yrs (n=12, range=20-30 yrs, mean=22.13)
- ONH: ≥65 yrs (n=12, range=67-75 yrs, mean=70.83)
- All participants had hearing thresholds ≤25 dB HL for 0.25-4 kHz.
- All participants had a passing score of ≥22 on the Montreal Cognitive Assessment (MoCA).

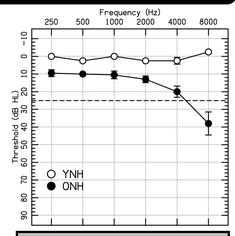


Figure 1: Average hearing thresholds for NH listeners. Error bars represent ±1 standard error.

METHODS

Stimuli

- 20-, 40-, 80-, 200-, and 400-pps pulse trains
- Bandpass filtered click trains
- BW=1000 Hz, CF=4000 Hz, 300-ms in duration
- 5th order bandpass Butterworth filters, double filtered
- Low frequency masking noise used to eliminate low frequency distortion products at 61.1 dB-A
  - Cutoffs: 200 Hz (3 dB/octave) and 1000 Hz (18 dB/octave)

Figure 2: Stimulus plot and noise

Perceptual

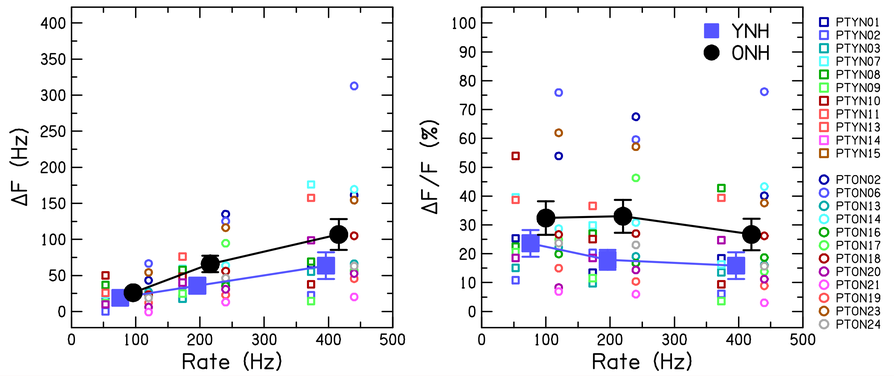
- Adaptive procedure, 3-down-1-up rule
- 3-interval-2-alternative-forced choice task
- Feedback provided
- Listeners identified which beep had the highest pitch
- Stimuli (80-, 200-, and 400-pps pulse trains) were presented monaurally to the right ear at 75 dB-A.
- Level roved over a 20 dB range.
- Frequency difference limens were measured as a function of stimulus rate presented.

Electrophysiology

- Auditory Steady State Responses (ASSR) to stimuli were recorded using the Intelligent Hearing Systems Smart EP continuous acquisition module.
- Stimuli presented monaurally (right ear) at 75 dB SPL through electromagnetically shielded insert earphones at 1.66 Hz rate.
- Minimum of 1000 artifact-free sweeps per condition
- Spectral energy corresponding to stimulus rate was calculated by taking the square of the absolute value of the convolution of the signal complex wavelet.

PERCEPTUAL RESULTS

Increasing rate worsens perceptual rate discrimination abilities



As rate increases, YNH and ONH listeners require greater differences in frequency (ΔF) in order to discriminate rate differences (ANOVA main effect of rate: $p < 0.05$).

There was no significant main effect of age or age×rate interaction ($p > 0.05$).

Figure 3: Average (solid symbols) and individual (open symbols) rate discrimination values for YNH listeners (squares) and ONH listeners (circle) as a function of rate. The error bars represent ±1 standard error.

ASSR RESULTS

YNH listeners have higher spectral energy for faster pulse rate conditions, suggesting ONH listeners may be experiencing temporal processing deficits when encoding rapid temporal information

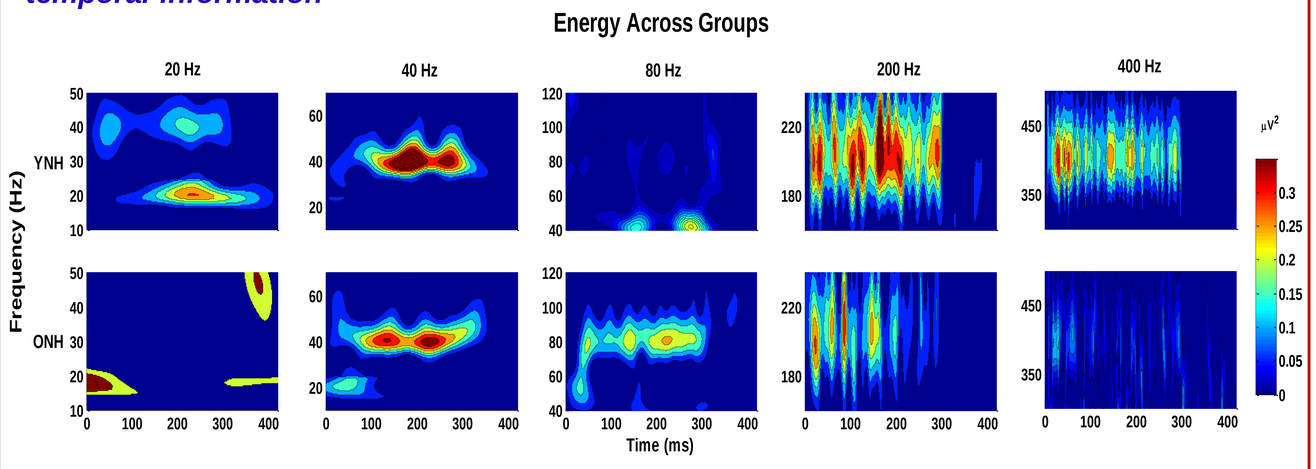
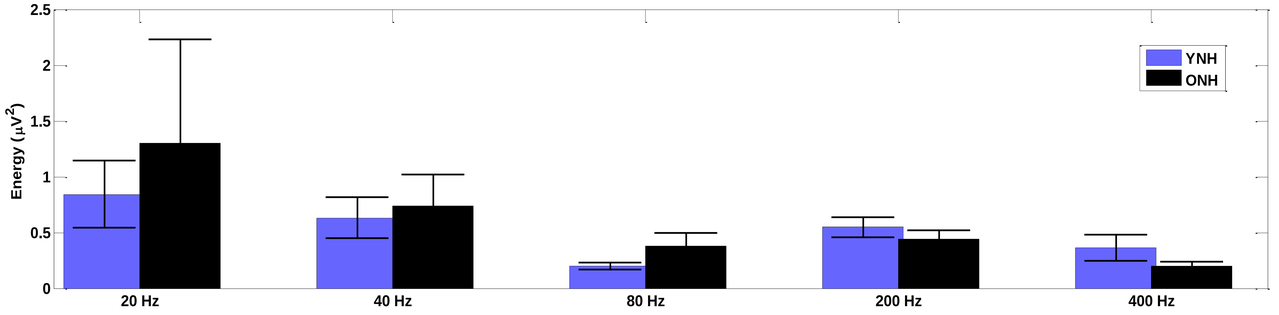


Figure 4 and 5: EEG spectral energy activity for all five pulse rates, represented in the time and frequency domain (above). Average EEG spectral energy as a function of pulse rate (below). Compares younger vs. older responses to the varied conditions. The error bars represent ±1 standard error. The data show a main effect of rate, suggesting shift in spectral energy??? as rate increases for all listeners.



PERCEPTUAL-ASSR RELATIONSHIP

Higher spectral energy relates to better frequency discrimination for the 200 Hz pulse rate condition.

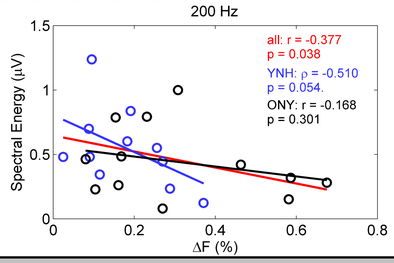


Figure 6: Average (gray line) and individual correlations between spectral energy responses and percent pulse rate discrimination for YNH (blue) and ONH (black) listeners obtained for the 200 Hz condition.

DISCUSSION

Perceptual:

- As rate increases, listeners require more larger absolute changes in frequency in order to discriminate changes in rapid temporal cues (Fig. 3).

Electrophysiological (ASSR):

- Spectral energy between listener groups was equivalent at the lower rates (20 and 40 Hz); however, the younger listeners had higher spectral energy compared to older listeners for the 200- and 400-pps conditions (Fig. 4).
- The differences in spectral energy responses between groups at faster rates suggests older listeners may experience limitations in encoding short duration timing cues due to temporal processing deficits (Fig. 4 and 5).

Perceptual-ASSR Relationship

- The 200 Hz correlation suggests there is a stronger relationship between younger NH listeners' perceptual and ASSR results than compared to the older NH listeners, which is reflected in the spectral energy (Figs. 4 and 6).

YNH-ONH Comparison

- The lack of age effects and interactions is likely contributed to smaller listener groups.

Future Directions

- Data collection is ongoing. Future analyses will determine if significant interactions are present between rate and age.

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