Lateralization biases for narrowband stimuli in listeners with typical and symmetrical hearing thresholds

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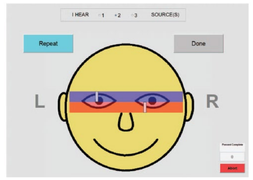
INTRODUCTION

- In spatial hearing, sound sources from directly in front of the listener receive zero interaural time difference (ITD) and zero interaural level difference (ILD).
- It is assumed that a zero interaural difference stimulus is perceived as centered for normal-hearing subjects, especially in careful headphone experiments measuring intracranial lateralization.
- **Purpose: Here we report that some subjects with normal and symmetrical hearing thresholds can perceive a zero interaural difference stimulus as not centered in the head.**

METHODS

- Intracranial lateralization task
  - Left-right lateralization provided by clicking 1, 2, or 3 image locations on bars on a face
  - 2 trials/condition/block
  - 20 trials/condition total
- Stimuli
  - 300, 400, 500, 600, 700 Hz
  - Tones and 50-Hz narrowband noises
  - 600-ms duration, 250-ms diotic temporal ramps
  - 63 dB SPL
  - ITDs = 0, ±125, ±250, ±375, ±500, ±625, ±750, ±1500 μs
- Headphones (HD265) reset and reversed after every testing block to diminish transducer biases



SUBJECTS

- 10 subjects (4 experts, 6 naïve)
- Normal (≤20 dB HL) and symmetric (≤10 dB) audiometric thresholds
- Audiometric thresholds measured using:
  - a double-walled sound booth
  - AudioStarPro Audiometer
  - Hughson-Westlake procedure

Subject		Frequency (Hz) 250	500	1000	2000	4000	8000
S1	Right	5	5	5	5	0	15
	Left	5	0	0	-5	-5	15
	Difference	0	**5**	5	10	5	0
S2	Right	-10	0	5	0	0	5
	Left	-5	0	-5	0	5	-5
	Difference	-5	**0**	10	0	-5	10
S3	Right	-5	-5	0	-10	-5	10
	Left	-5	-5	0	-5	-5	5
	Difference	0	**0**	0	-5	0	5
S4	Right	5	5	0	0	0	10
	Left	0	5	0	0	0	15
	Difference	5	**0**	0	0	0	-5
S5	Right	0	-5	0	-5	-5	5
	Left	5	0	-5	0	0	5
	Difference	-5	**-5**	5	-5	-5	0
S6	Right	5	5	5	5	-5	15
	Left	10	5	5	5	0	15
	Difference	-5	**0**	0	0	-5	0
S7	Right	5	5	5	5	5	10
	Left	10	5	5	0	0	0
	Difference	-5	**0**	0	5	5	10
S8	Right	10	5	0	5	-5	0
	Left	5	10	0	5	0	5
	Difference	5	**-5**	0	0	-5	-5
S9	Right	5	5	0	5	-5	5
	Left	10	10	5	5	0	10
	Difference	-5	**-5**	-5	0	-5	-5
S10	Right	5	10	0	0	-5	-10
	Left	5	5	-5	-5	-10	-10
	Difference	0	**5**	5	5	5	0

Table 1. Audiometric thresholds for the right and left ears, and their difference. The right-left difference in threshold at 500 Hz is highlighted in bold.

STIMULI THAT SHOULD BE PERCEIVED AS CENTERED IN THE HEAD ARE SOMETIMES NOT

Individual variability in intracranial lateralization at different frequencies for listeners with symmetrical audiometric thresholds

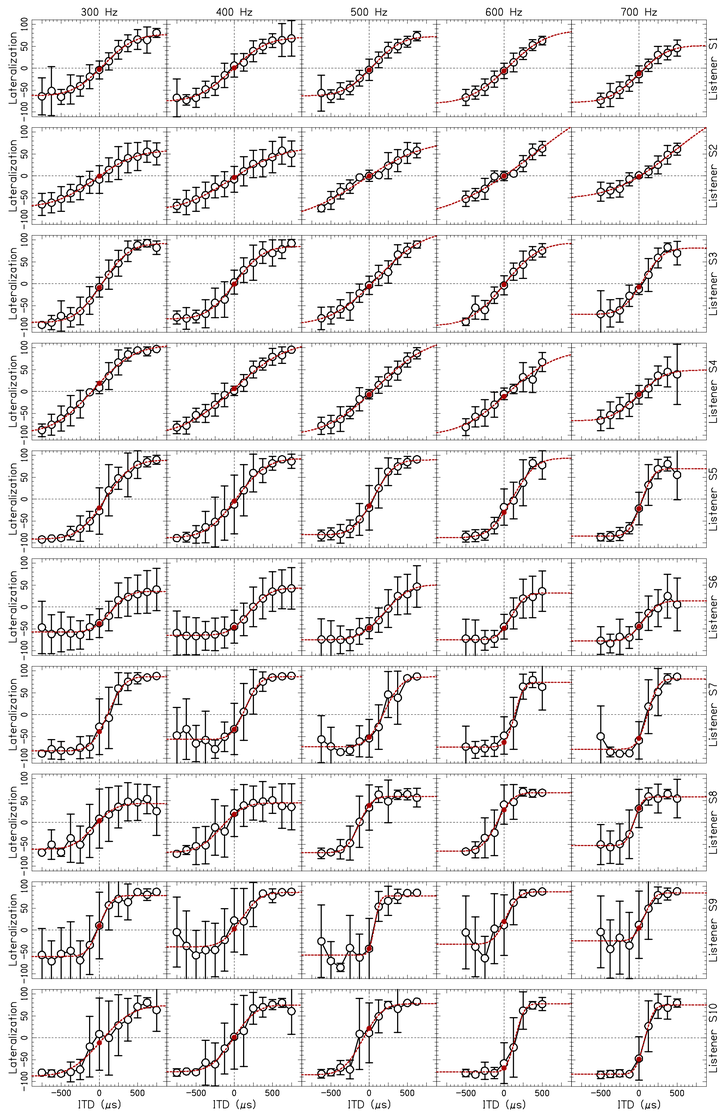


Figure 1: Individual lateralization responses in percentage from midline to left (negative) or right (positive) ear as a function of ITD for tones. Error bars represent ±1 standard deviation across the trials. Dashed lines represent cumulative Gaussian fits to the data. The filled solid circle represents the y-intercept (i.e., the lateralization bias) at 0-μs ITD. Points beyond ±7π/8 are omitted to avoid lateralization ambiguities that occur at the π boundary.

Expert subjects, psychoacousticians, co-authors are all centered (S1-S4)

Naïve subjects that show leftward lateralization bias across all frequencies (S5-S7)

Lateralization biases are usually consistent using tones and narrowband noises

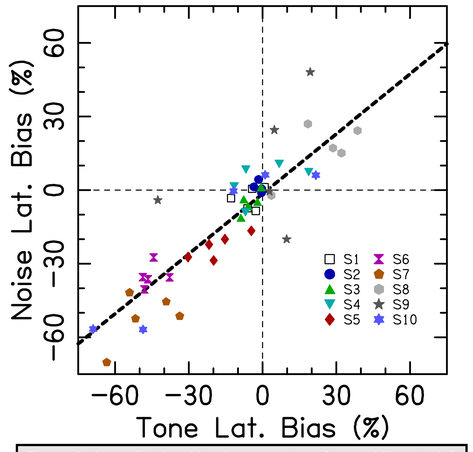


Figure 2: Lateralization bias in percentage from midline to left (negative) or right (positive) ear for tones (x axis) and narrowband noises (y axis). There are five points per listener (for the five CFs), and each listener is represented by a different symbol.

Naïve subjects that show leftward or rightward lateralization bias at a subset of frequencies (S8, S10)

A naïve subject that had high response variability (S9)

WHY WERE THESE BIASES NOT FORMALLY REPORTED BEFORE?

It is surprising that lateralization biases of this kind have not been previously reported despite decades of intracranial lateralization experiments. Careful inspection of the literature suggests that these biases have been observed, but not reported for various reasons including:

1. Assumed lateralization biases a result of equipment (e.g., headphone placement)
2. Obscured by analysis
   - Data normalization
   - Reporting group averages, not individual data
3. Obscured by procedures
   - Using a lateralization pointing task at same frequency of bias
   - Application of "small" ILD to achieve center, but not reporting that amount formally
4. Subject recruitment biases
   - Small sample sizes
   - Using only "expert and reliable" subjects (e.g., co-authors and lab members)
   - Dismissing "problematic" subjects

WHY MIGHT LATERALIZATION BIASES OCCUR?

1. Suprathreshold deficits (i.e., hidden hearing loss)
2. Procedural effects (range biases, visual influences, training effects)

FUTURE DIRECTIONS

1. Determine prevalence in a large number of naïve subjects
2. Include more extensive audiological workup than just hearing thresholds (ABRs, OAEs, etc.)
3. Longitudinal testing to verify lateralization biases persist over multiple days
4. Determine if lateralization biases occur for only low-frequency narrowband stimuli
5. Determine if lateralization biases affect other spatial-hearing tasks (e.g., free-field sound localization, spatial release from masking, interaural discrimination, ILD lateralization)
6. Determine if lateralization biases affected by procedural issues (e.g., range biases, visual influences)

REFERENCE

Goupell, M. J., Best, V., and Colburn, H. S. (**2021**) "Intracranial lateralization bias observed in the presence of symmetrical hearing thresholds," *JASA Express Letters.* 1 (10), 104401.

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