

Sensibilité directionnelle de la sonie pour des bruits et des sons familiers

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In memory of Jean-Claude Risset

1. INTRODUCTION

- * Binaural loudness in free field depends on the azimuthal and vertical positions of the sound source relative to the listener (Sivonen and Ellermeier, 2006; Sivonen, 2007; Vannier, 2015).
- Directional Loudness Sensitivity (DLS) is the difference in level between a frontal (reference) and a nonfrontal (test) position of the sound source at the point of subjective equality (PSE) in loudness.
- While the level of the sound source at the theoretical center of the head is constant in DLS measurements, the level at the entrance of the ear canals depends on source position, as a result of the directiondependent signal filtering by the Head Relative Transfert Functions (HRTFs).
- * Previous studies reported large interindividual differences in DLS, which were not completely explained by individual differences in HRTFs nor by differences in loudness functions (Vannier, 2015).
- It has been proposed that loudness constancy could possibly explain why some listeners show little or no DLS (Sivonen and Ellermeier; 2006).

2.OBJECTIVES

- Assess interindividual differences in DLS within a large listeners sample and for various source positions.
- Test broadband noise in free field vs narrow-band used in the literature (except in Sivonen, 2007, using binaural synthesis).
- Test the loudness constancy hypothesis.

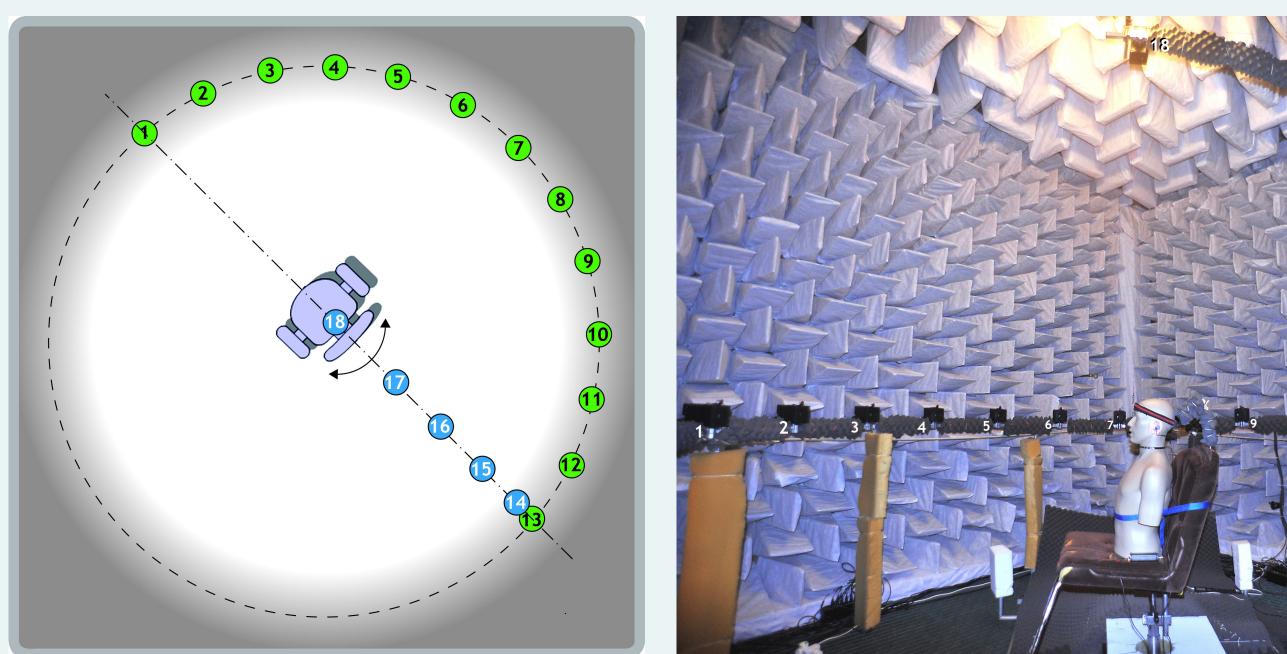


Figure 1. Schematic view and picture of the experimental set-up.

3. APPARATUS

- Free field listening (anechoic room), 13 horizontal (spaced 15° apart) and 5 vertical loudspeakers (15, 30, 45, 60 and 90°) at 2m each from the center of the head (Fig. 1).
- Listener seated on rotating chair face to 1 of the 13 horizontal loudspeakers.
- Head supported by a headrest and maintained by a headband with the entrance of listener's ear canals aligned with the center of horizontal loudspeakers.
- \star => 66 possible Test positions of the source in the right upper part of the listener's space.

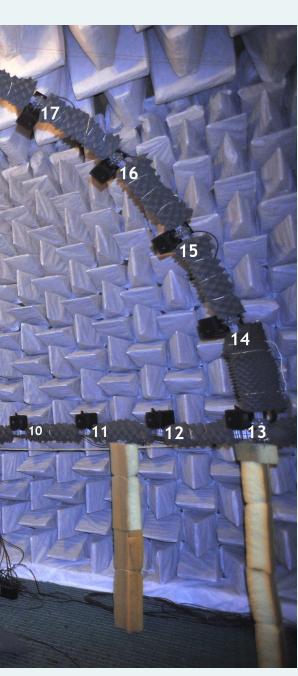
4. METHOD

* **2AFC interleaved procedure:** Pair of sounds, 1 from the frontal REFERENCE position with a fixed level of 65 dB SPL, 1 from one of 66 possible TEST positions with variable level. Task: which one was louder? Two starting levels of the test sound: 8 dB above or below the reference level. * Adapting rules: 2down-1up (for starting level = 8 dB above) or 1down-2up (for starting level = 8 dB below). Level increment/decrement : 4 dB until the 4th reversal and 1 dB until the 10th reversal. Interleaved procedure: 1 bloc = 8-10 runs = 4-5 TEST positions * 2 starting levels. * "Partial DLS" (for 1 run) = [Reference - Test] level averaged across the last 6 reversals. * DLS at the PSE (for 1 TEST position) = Partial DLS averaged across 2 starting levels x 2 repetitions.

INTERINDIVIDUAL DIFFERENCES IN DIRECTIONAL LOUDNESS SENSITIVITY

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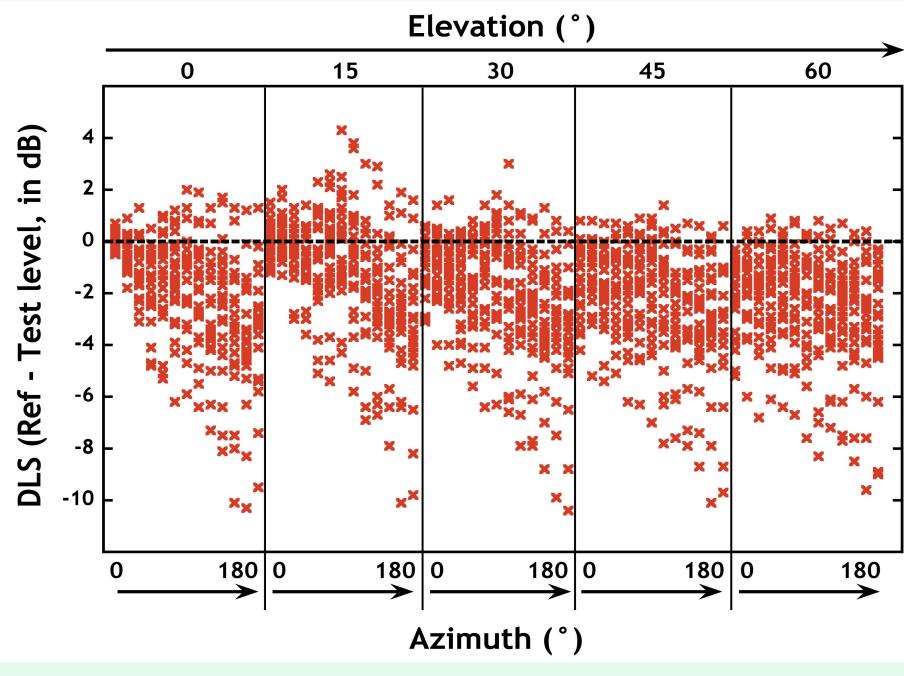
5.EXPERIMENT 1: WHITE NOISE



- **Stimulus:** White Noise (160-17 000 Hz) with duration of 1 sec.
- Listeners: 25 naive young adults with normal hearing, equally distributed in gender and musical experience (8 in Sivonen and Ellermeier, 2006; 17 in Vannier, 2015).
- **At-ear levels:** Measured with blocked ear canals for all loudpeasker positions in 23 of the 25 listeners.

Results

• **DLS mainly < 0:** Test sounds mostly perceived less loud than frontal Reference (Fig. 2 and 3). Interindividual differences in DLS sign and magnitude are large and increase with azimuth (Fig. 2). Effect of azimuth on DLS decreases as elevation increases (Fig. 3).



values of DLS obtained elevation (5) and azimuth (13 from 0 to 180°). Each symbol reprethe individual mean of 4 partial DLS estimates (2 starting levels *

- fitted with robust linear regression, for 21/23 listeners when all test positions are included (Fig. 4).
- **Slope** of linear fit always < 1: DLS varies less than the level difference at the right ear (Fig. 4).
- for by difference in at-ear level (r2; range = 3 to 71%), see values in Fig. 4.

Individual against difference in level at ight ear. Each panel for a different listener. Each symbol is for a different position (N = 66). The data were fitted with linear regressions whose r2 and slope are reported (in red for significant correlations, grey otherwise). The green diagonal represents perfect relationship (slope = 1). The at ear measurement were done on 23 listerners.

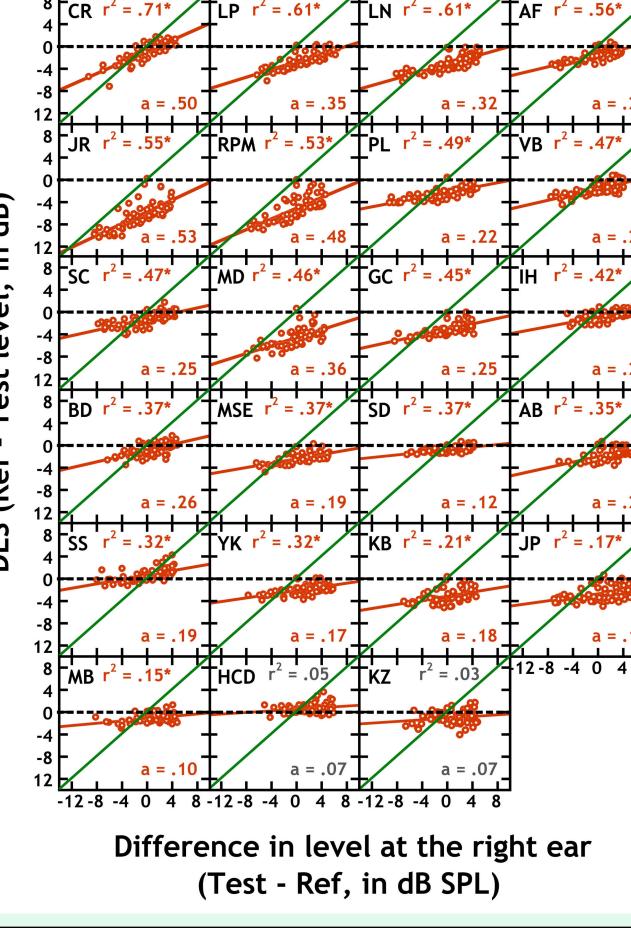
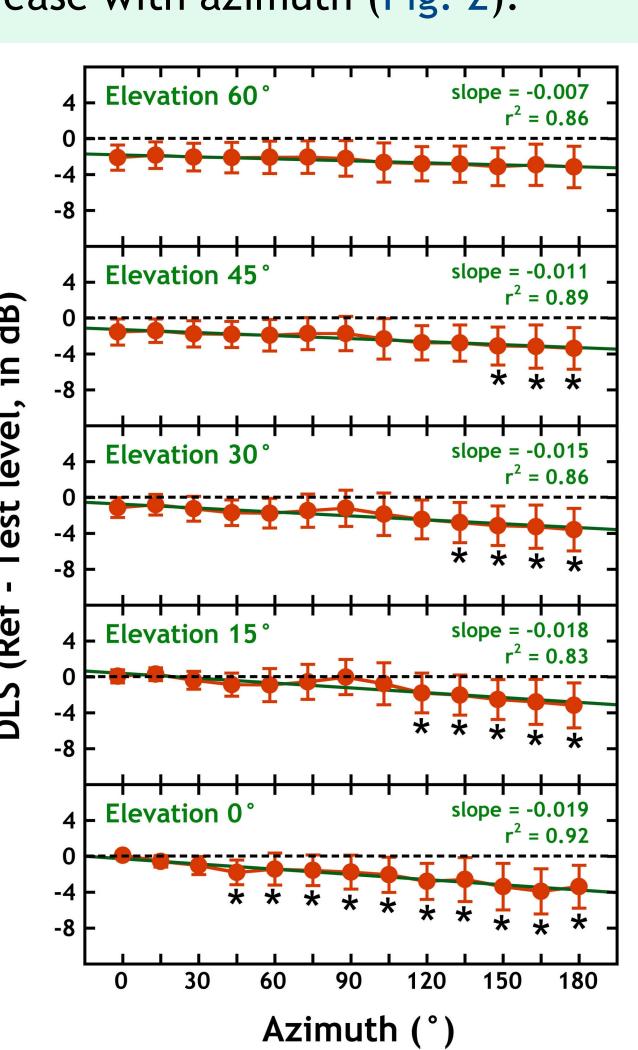




Figure 3. DLS averaged across the 25 listeners as a function of imuth for each elevation (from - 1 standard deviation. The lata were fitted with linea egressions whose slope and corners. Stars show the DLS that differ from that ned for the 0°-azimuth the same elevation according to post-hoc Scheffé tests.



Difference (Test - Reference) in level at the right ear significantly correlated with DLS, and relationship

Large individual differences in slope (range = 0.07 to 0.50) and in part of the variance in DLS accounted

Linear relationships are often robust for low elevations but weaken as elevation increases (Table 1).

	r ² o	of the relat	ionship be	etween					
Listener	DLS and Difference in level at the right ear for each elevation								
	0°*	15°	30°	45 °	<u>60°</u>				
CR	0.90	0.80	0.76	0.59	0.48				
LN	0.88	0.70	0.66	0.41	0.42				
HCD	0.81	0.28	0.64	0.11	0.26				
SC	0.81	0.63	0.56	0.36	0.02				
GC	0.80	0.52	0.39	0.28	0.40				
JR	0.72	0.59	0.59	0.48	0.25				
LP	0.70	0.66	0.69	0.60	0.18				
MD	0.69	0.49	0.65	0.58	0.33				
VB	0.64	0.49	0.41	0.61	0.41				
RPM	0.62	0.48	0.57	0.59	0.52				
SS	0.57	0.12	0.13	0.73	0.44				
AF	0.56	0.63	0.72	0.54	0.37				
PL	0.49	0.53	0.46	0.40	0.4				
MSE	0.49	0.39	0.36	0.41	0.20				
SD	0.47	0.49	0.33	0.19	0.04				
YK	0.42	0.45	0.36	0.52	0.37				
AB	0.39	0.54	0.46	0.49	0.35				
BD	0.35	0.81	0.56	0.17	0.09				
KB	0.33	0.33	0.11	0.16	0.10				
KZ	0.25	0.19	0.12	0.00	0.37				
JP	0.22	0.36	0.28	0.08	0.01				
IH	0.16	0.07	0.00	0.00	0.17				
MB	0.08	0.29	0.10	0.22	0.26				

Table 1. Individual r2 of the relationship etween DLS and ference in level at ght ear for eac vation. Red value now significan[®]

- Vannier, 2015; Sivonen, 2007).

6.EXPERIMENT 2: "NATURAL" SOUNDS AND FILTERED WHITE NOISE

Stimuli: Organ (1.6 sec), Applause (1sec) + Filtered white noise (1 sec), see spectrum in Fig. 5. **Listeners:** 9 with large DLS in Experiment 1 for 7 Test positions selected from Experiment 1 (Table 2).

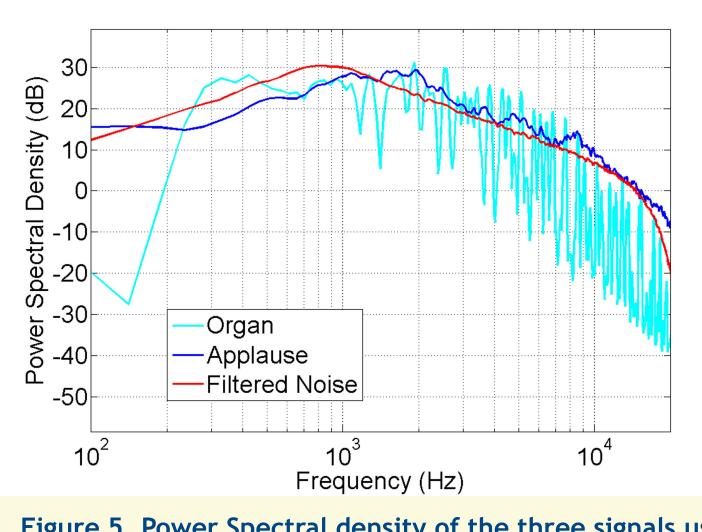


Figure 5. Power Spectral density of the three signals used in Experiment 2 (organ, applause, filtered noise).

Results and Discussion

- (Fig. 6).
- from differences in spectral envelop.
- judgments.

* Large DLS is observed for broadband noise and is only partially accounted for by at-ear levels.

Sivonen and Ellermeier (2006). Directional loudness in an anechoic sound field, head-related transfer function, and binaural summation, J. Acoust. Soc. Am. 119. Sivonen (2007). Directional loudness and binaural summation for wideband and reverberant sounds, J. Acoust. Soc. Am. 121. Vannier (2015). Sonie de champs acoustiques stationnaires en situation d'écoute dichotique. PhD Thesis, Institut National des Sciences Appliquées, Lyon, France. Florentine and Epstein (2012). Binaural loudness summation for speech presented via earphones and loudspeaker with and without visual cues. J. Acoust. Soc. Am. 131 This work was supported by the project LoudNat funded by the French National Research Agency ANR-11-BS09-016-07



Discussion

DLS magnitude larger for white noise than for 1/3-oct-band or pink noise (Sivonen and Ellermeier, 2006;

Individual DLS are only partially accounted for by differences in at-ear level, in agreement with previous studies. The degree of contribution of these level differences strongly varies between listeners.

Hypothesis: Are listeners with smaller DLS more sensitive to loudness constancy?

Florentine and Epstein (2012): Binaural loudness constancy is stronger with familiar sounds.

white noise (in black).

Hypothesis for Experiment 2: Is the DLS reduced if familiar sounds are used?

Indivual DLS obtained in Experiment 1												
		by Test	averaged across									
Listener	45, 0	45, 30	45, 60	90, 0	120, 0	150, 0	180, 0	positions				
JR	-4.8	-4.7	-6.1	-5.9	-7.3	-10.1	-9.5	-6.9				
MD	-4.7	-3.4	-4.1	-4.2	-6.3	-7.5	-7.4	-5.4				
RPM	-4.1	-3.9	-4.9	-4.7	-3.8	-8.0	-7.4	-5.3				
GC	-3.1	-4.0	-3.8	-2.2	-3.4	-4.8	-5.3	-3.8				
KB	-3.1	-3.2	-2.9	-3.4	-5.0	-4.7	-4.1	-3.8				
LN	-2.5	-1.6	-4.1	-2.3	-4.2	-5.2	-5.8	-3.6				
PL	-1.3	-2.6	-3.1	-3.2	-3.5	-3.1	-3.1	-2.8				
YK	-2.2	-1.9	-1.3	-2.3	-3.7	-3.6	-3.0	-2.6				
AB	-1.4	-0.4	-0.7	-1.5	-3.6	-3.4	-2.9	-2.0				

Table 2. Test positions (in blue) and listeners (in red) investigated in

DLS smaller for familiar sounds (organ and applause) than for white noise

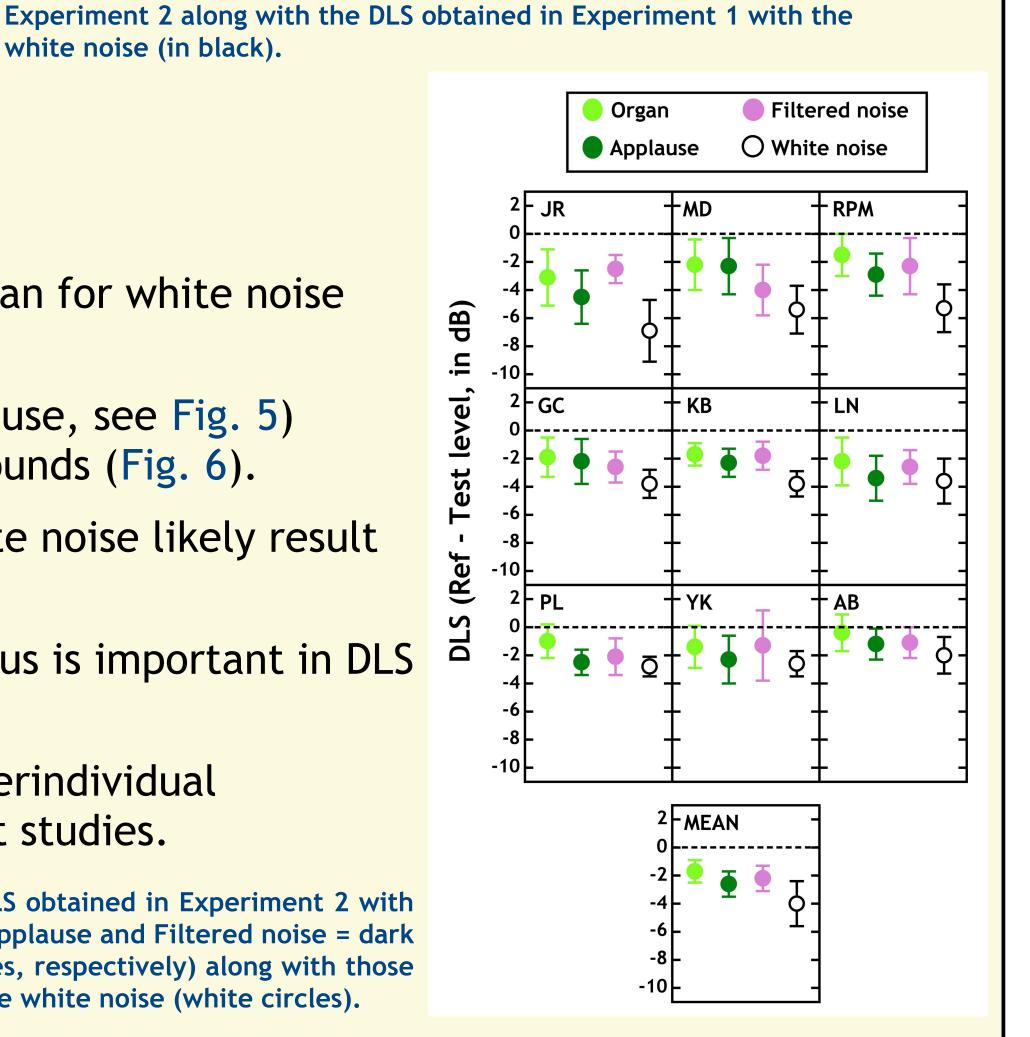
DLS for filtered noise (spectral envelop similar to applause, see Fig. 5) smaller than for white noise but identical to familiar sounds (Fig. 6).

=> Differences in DLS between familiar sounds and white noise likely result

 \sim => Energy in the high-frequency spectrum of the stimulus is important in DLS \overline{a}

=> Experiment 2 provided no explanation about the interindividual differences in DLS observed in Experiment 1 and in past studies.

> dividual and mean DLS obtained in Experiment 2 with each different stimulus (Organ, Applause and Filtered noise = dark light green and pink circles, respectively) along with those ined in Experiment 1 with the white noise (white circles)



6.CONCLUSION AND PERSPECTIVES

Individual computation of binaural gain and of at-ear level in the high-frequency part of the signal are in process so as to further identify factors that may have contributed to our perceptual result.

Further research is needed to evaluate the possible contribution of loudness constancy to DLS judgments.