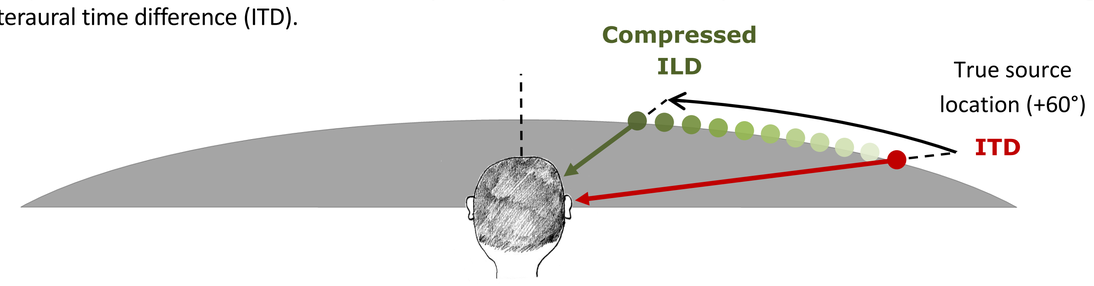
Effects of dynamic-range compression on perceived lateral position

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1. Introduction

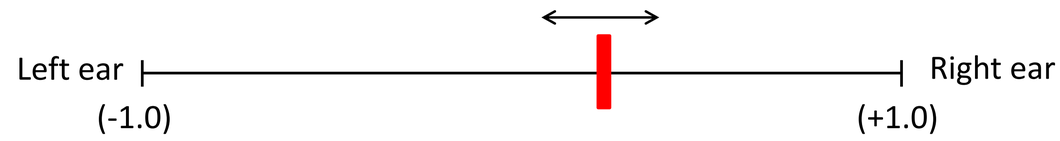
Dynamic-range compression is used in hearing aids and cochlear implants to control the range of incoming sound levels. If compression acts independently at each ear in a bilateral fitting, interaural level differences (ILDs) are disturbed. The ILD is one of two primary cues for the lateral position of a sound, the other being the interaural time difference (ITD).



While past studies have found compression to have little impact on sound localization performance [1–2], we identified certain conditions in which compression does adversely affect spatial perception [3]. Here we test whether compression affects quantitative judgements of lateral position in those same conditions.

2. Method

Perceived lateral position measured using a line-dissection method



Rather than indicating an overall position, 11 normal-hearing listeners judged on separate trials (1) the **leftmost extent** and (2) the **rightmost extent** of the auditory event.

On each trial, one of three **response options** was chosen according to what was heard:

1. A 'single, stationary image' (whether focused or diffuse)
2. A 'moving or gradually broadening image'
3. A 'split image' (i.e., the sound appeared at more than one position at the same time)

3. Stimuli

How do the effects of compression depend on stimulus characteristics?

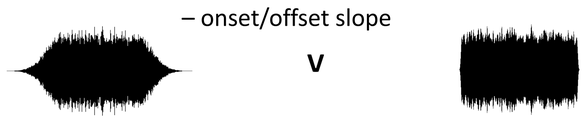
Seven stimuli including: Speech +



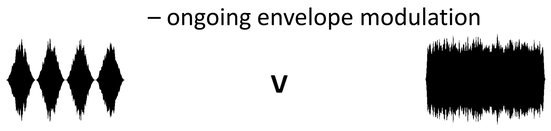
"They moved the furniture."

Synthetic stimuli designed to test the effect of:

– onset/offset slope



– ongoing envelope modulation



– timing of pulses relative to compression time constants



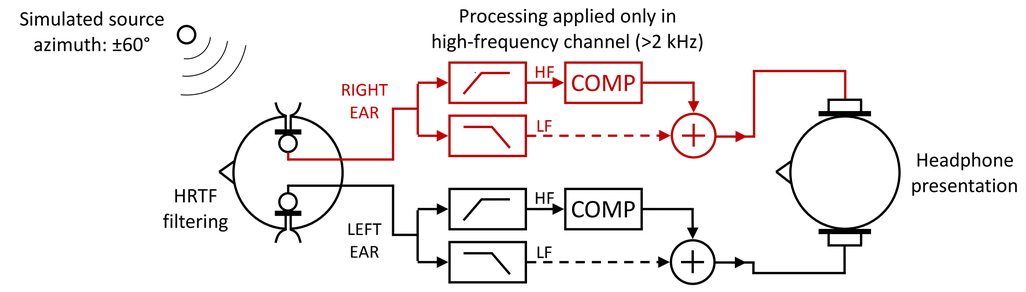
Duration: 1 – 1.8 seconds

Bandwidth (noise stimuli): 200 Hz – 8 kHz (pink spectrum)

Level: 65 dB SPL

4. Processing

Contrasting the dynamic ILD changes introduced by compression to a static ILD bias



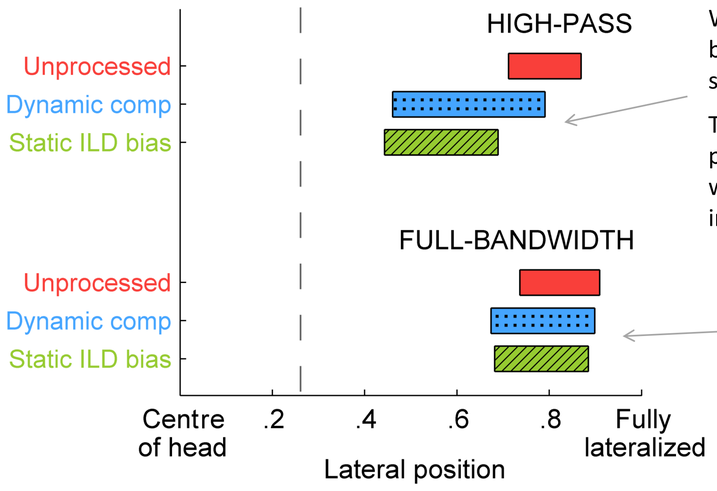
Three high-frequency-channel processing conditions:

– **Unprocessed** (natural binaural cues)
– **Dynamic compression** (3:1, fast-acting, wide-dynamic-range)
– **Static ILD bias** (static 3:1 reduction of long-term ILD)

Two bandwidth conditions:

– **High-pass** (listen to HF channel only)
– **Full-bandwidth** (listen to LF & HF channels recombined)

5. Reduction in high-frequency ILD shifted the auditory event towards the centre of the head



When only high frequencies were present, both types of processing produced a moderate shift towards the centre of the head.

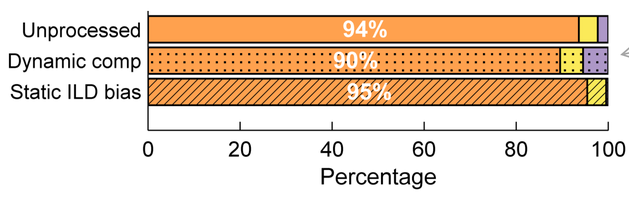
The shift was not as great as would be predicted from the 3:1 reduction in ILD if this was the only salient cue (predicted position indicated by the dashed grey line).

When undisturbed low-frequency cues were made available, the size of the effect was markedly reduced.

- Group-average data
- All results referred to the right hemisphere (left–right symmetry assumed)
- Boxes extend from the median leftmost extent to the median rightmost extent (across all trials)

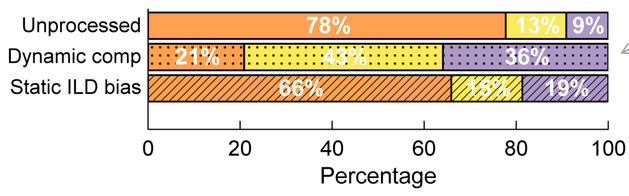
6. Compression increased the occurrence of moving/split images for gradual-onset sounds

Sounds featuring only abrupt onsets & offsets
(e.g. FAST ONSET NOISE BURST)

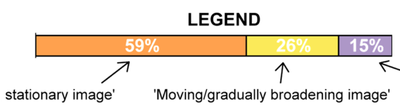


For sounds featuring relatively abrupt onsets & offsets, a 'single, stationary image' was reported on most trials and the processing had little effect on response-option use.

Sounds featuring more gradual onsets & offsets
(e.g. SPEECH)

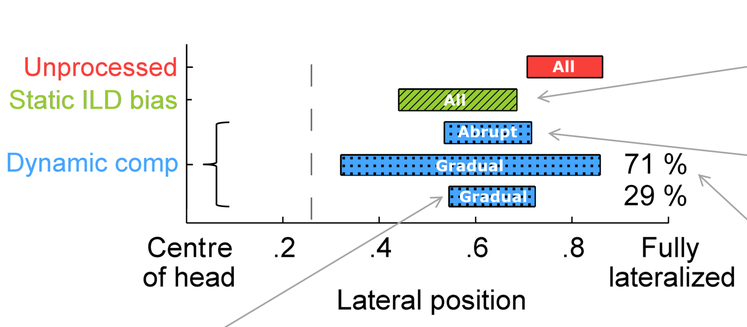


For sounds featuring more gradual onsets & offsets (inc. speech), dynamic compression substantially increased the occurrence of moving & split images. Interestingly, the static ILD bias still had only a minor influence on response-option use.



- Group-average data
- High-pass condition

7. Lateralization responses differed when compression gave rise to a moving/split image



(1) The static ILD bias generally did not change response-option use and the entire image was shifted centrally...

(2) ... dynamic compression had a similar effect on sounds featuring only abrupt onsets & offsets.

(3) On most trials (71%), sounds featuring more gradual onsets & offsets were perceived as a moving or split image after dynamic compression — only the innermost extent shifted towards the centre, resulting in a much **wider overall lateral extent**.

(4) But on 29% of trials these sounds were still perceived as a 'single, stationary image' — the entire image was shifted centrally and the overall lateral extent was unaffected (just like for a static ILD bias). This primarily reflected **individual differences** between listeners.

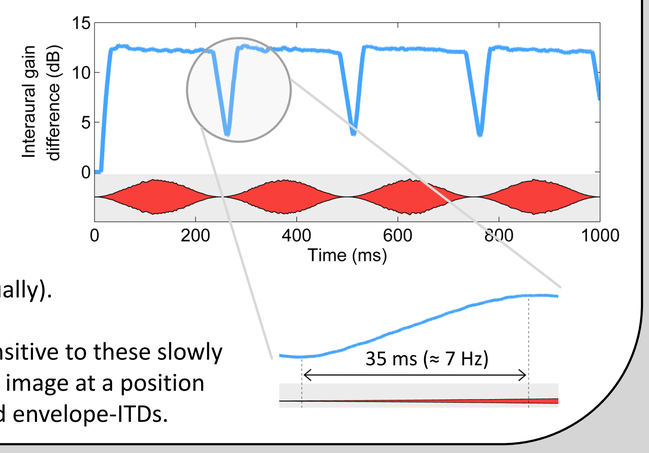
8. ILDs were perceptually more salient when compression caused them to change slowly

In the high-pass condition (>2 kHz), ILD and envelope-ITD were the primary cues supporting lateralization.

As long as a 'single, stationary image' was perceived, the image shifted only about half as far towards the centre as would be predicted from the 3:1 reduction in ILD, implying **roughly equal weighting of ILDs and envelope-ITDs.**

But if, after dynamic compression, a moving/split image was reported, the innermost extent approached the position suggested by the 3:1 compressed ILD, implying near **ILD dominance** for this extent.

We analysed the **rate at which compression caused ILDs to change during onset regions:** (e.g. for SAM NOISE BURST →)



For the stimuli in which moving/split images were reported and ILDs played their largest role in determining the lateral extents, **compression caused ILDs to change at rates of about 2–7 Hz** (the kind of rates that may be followed in detail perceptually).

However, a few listeners seemed relatively insensitive to these slowly varying ILDs, continuing to respond with a fused image at a position corresponding to a weighted average of ILDs and envelope-ITDs.

9. Conclusions

- Compression acting independently at each ear can affect the perceived lateral position of sounds.
- Compression gave rise to the perception of moving/split images for sounds featuring gradual onsets & offsets.
- The severity of the effects was reduced when listeners had access to undisturbed low-frequency cues.
- Listeners generally gave roughly equal weight to ILDs and envelope-ITDs at high frequencies, although if compression caused ILDs to vary slowly and a moving/split image was perceived, ILDs played a greater role.
- The results suggest new test conditions in relation to the use of compression in hearing devices.

[1] Musa-Shufani, S., Walger, M., von Wedel, H., *et al*. (**2006**). "Influence of dynamic compression on directional hearing in the horizontal plane," Ear Hear. **27**, 279–285.
[2] Keidser, G., Rohrseitz, K., Dillon, H., *et al*. (**2006**). "The effect of multi-channel wide dynamic range compression, noise reduction, and the directional microphone on horizontal localization performance in hearing aid wearers," Int. J. Audiol. **45**, 563–579.
[3] Wiggins, I., and Seeber, B. (**2011**). "Effects of dynamic-range compression on the spatial attributes of sounds in normal-hearing listeners," Ear Hear. (in press).

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