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Cross-frequency effects on loudness asymmetry in real-room reverberation

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Background

Test sounds with "damped" temporal envelopes are less loud than "ramped" sounds". An excitation-pattern model (Glasberg & Moore, 2002) can account for this difference. However, the loudness difference is more apparent when test sounds are compared with preceding standards that are damped than when preceded by ramped ones (Stecker & Hafter, 2000).

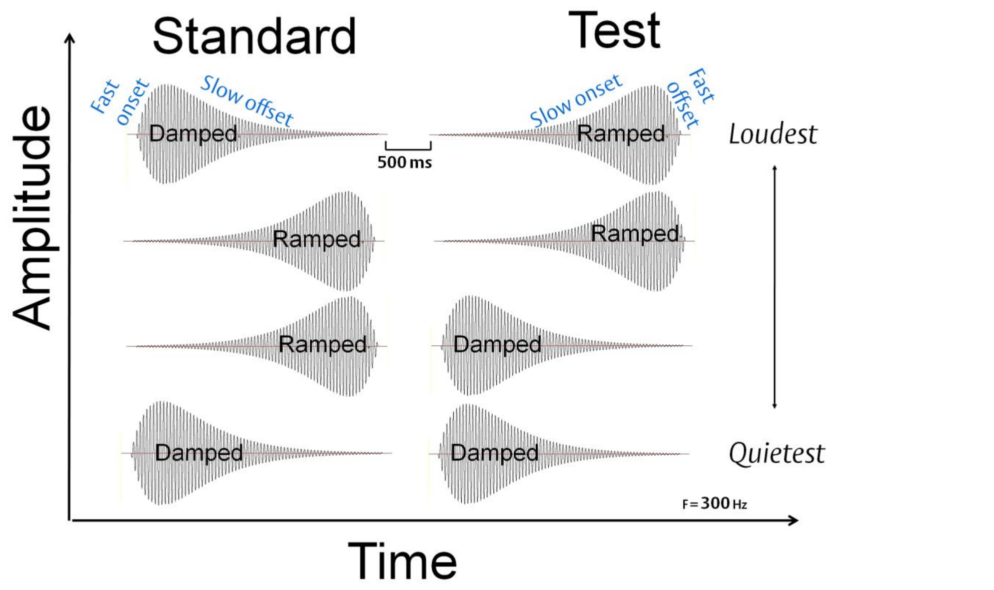

Fig 1. Ramped and damped pairings, as used by Stecker & Hafter (2000) in obtaining relative loudness judgements.

This 'loudness context effect' might be due to the resemblance of damped offsets and the decaying 'tails' caused by the reflected sound in everyday listening environments.

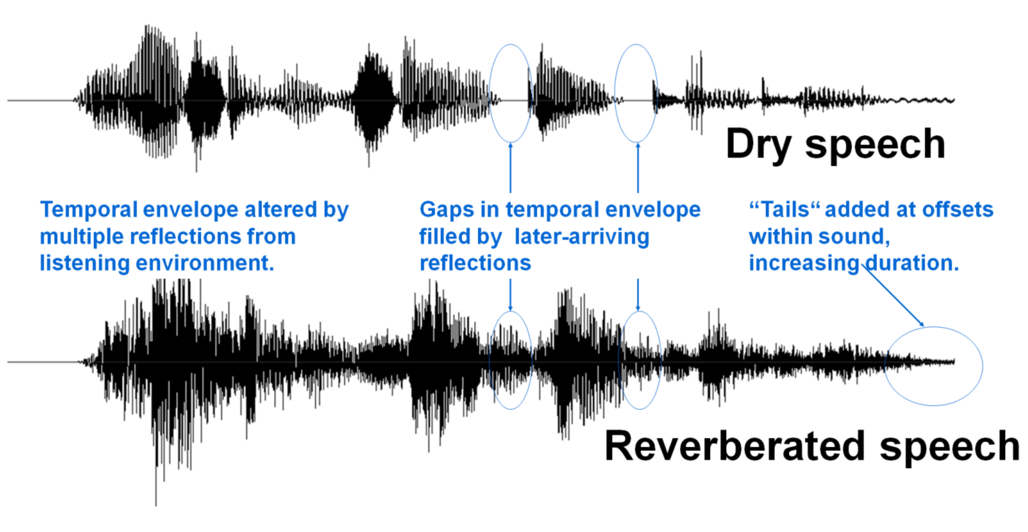

Fig 2. Waveforms showing effect of real-room reverberation on speech.

Stecker & Hafter suggested that successive sounds with similarly long tails may result in a 'perceptual constancy'. Slow-offset sounds are parsed into two parts, separately giving information 1) about the sound source and 2) about the listening environment. Therefore, energy in a decaying tail may be discounted from loudness assessments if listeners judge only the source.

Raimond & Watkins (2009) found that loudness context effects are greater with longer, real-room reflection-patterns convolved with pure tones to create reverberation-damped and –ramped stimuli and more prominent with monaural presentation.

In this experiment, we ask whether loudness differences between reverberation-ramped and -damped sounds are still apparent when standards and tests are at different frequencies.

Room-impulse responses (RIRs)

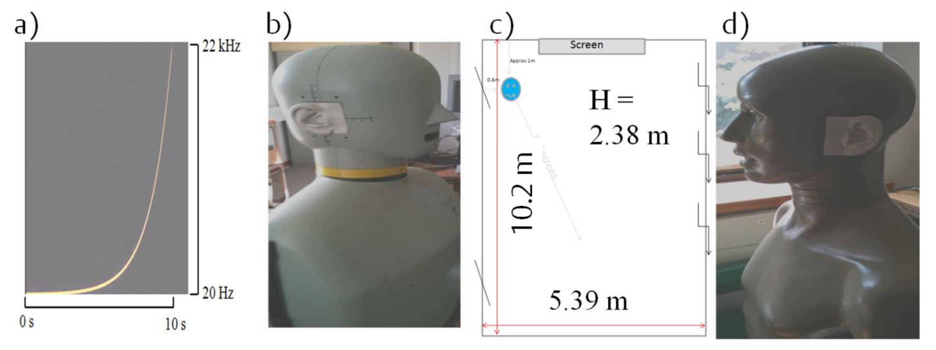

Fig 3a) Swept-sine measurement signal; b) played through KEMAR dummy with directional transducer mouthpiece; c) in real room; d) recorded at head-and-torso-simulator with mikes in ears; When RIRs are convolved with a sound and played over headphones, a listener should experience the sound as if heard in the original room.

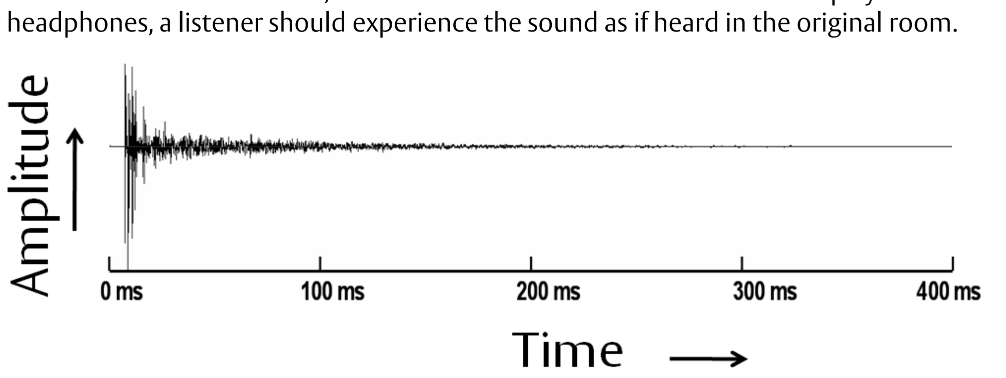

Fig 4. RIR recorded in a real seminar–room with a distance of 2.50 m between source and listener, giving a ratio of early (50 ms) to late energy of 9.71 dB (C50, left ear, A-weighted). Recorded using Farina's swept-sine method (2000).

Reverberation-damped and –ramped tones

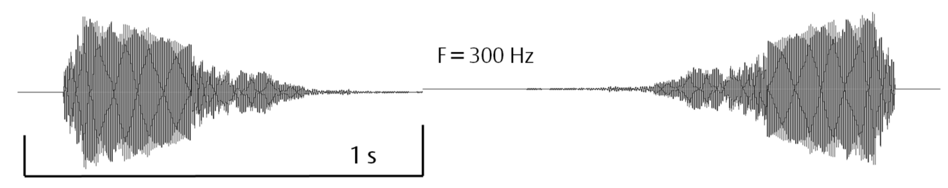

Fig 5. On the left is a 300-Hz tone convolved with an RIR to produce the 'reverberation-damped' 300-Hz stimulus. On the right is the time-reversed version, which is the 'reverberation-ramped' 300-Hz stimulus. The procedure was separately repeated for the 1500-Hz stimuli.

Cross-frequency pairings

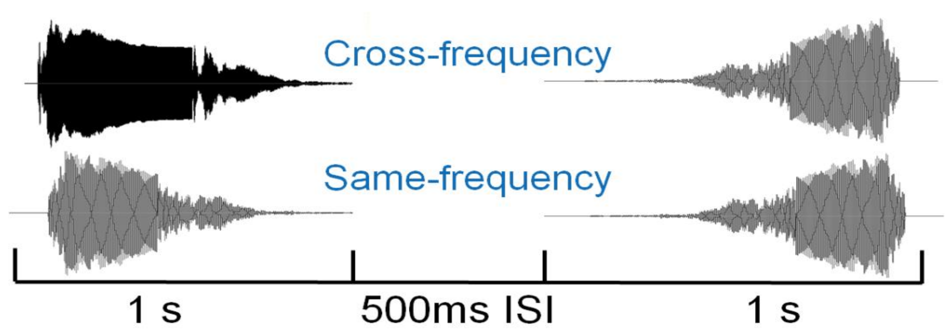

Fig 6. Examples of cross-frequency and same-frequency, RIR-shaped pairings. On top, a 1500 Hz-damped standard followed by a 300Hz ramped test. On the bottom, a 300 Hz damped standard followed by a 300 Hz ramped test

Conditions

Three factors: **envelope-order** (damped standard with ramped test, damped with damped, ramped with ramped and ramped with damped), **same-vs cross-frequency** (300 Hz Standard with 300 Hz Test and 1500 Hz Standard with1500 Hz Test vs1500 Hz Standard with 300 Hz Test and 300 Hz Standard with1500 Hz Test) and **test sound level** (70, 72, 74, 78, 80, 82, 82, 86, or 90 dB SPL).

Procedure

On each trial, listeners seated in an IAC 1201 booth heard one of the 4 'reverberation-damped with -ramped pairings over the left channel of headphones, and they responded with a two-interval relative-loudness judgment (2IC). The 80-dB SPL standard was always the first of the pair and it was followed by a test sound whose 9 possible levels were selected from an 18-dB range around 80 dB SPL. The ISI in each trial was 500ms. Listeners clicked one of two buttons on a computer screen viewed through the booth's window (first or second sound 'is louder'). 300-Hz and 1500-Hz standards were judged in different trial-blocks, so that each block had two of the 4 types of envelope-pairing. There were three repeats of each trial-type in a block's randomised 432-trial sequence. Four participants completed both of these blocks ten times in separate experimental sessions.

Individual Data

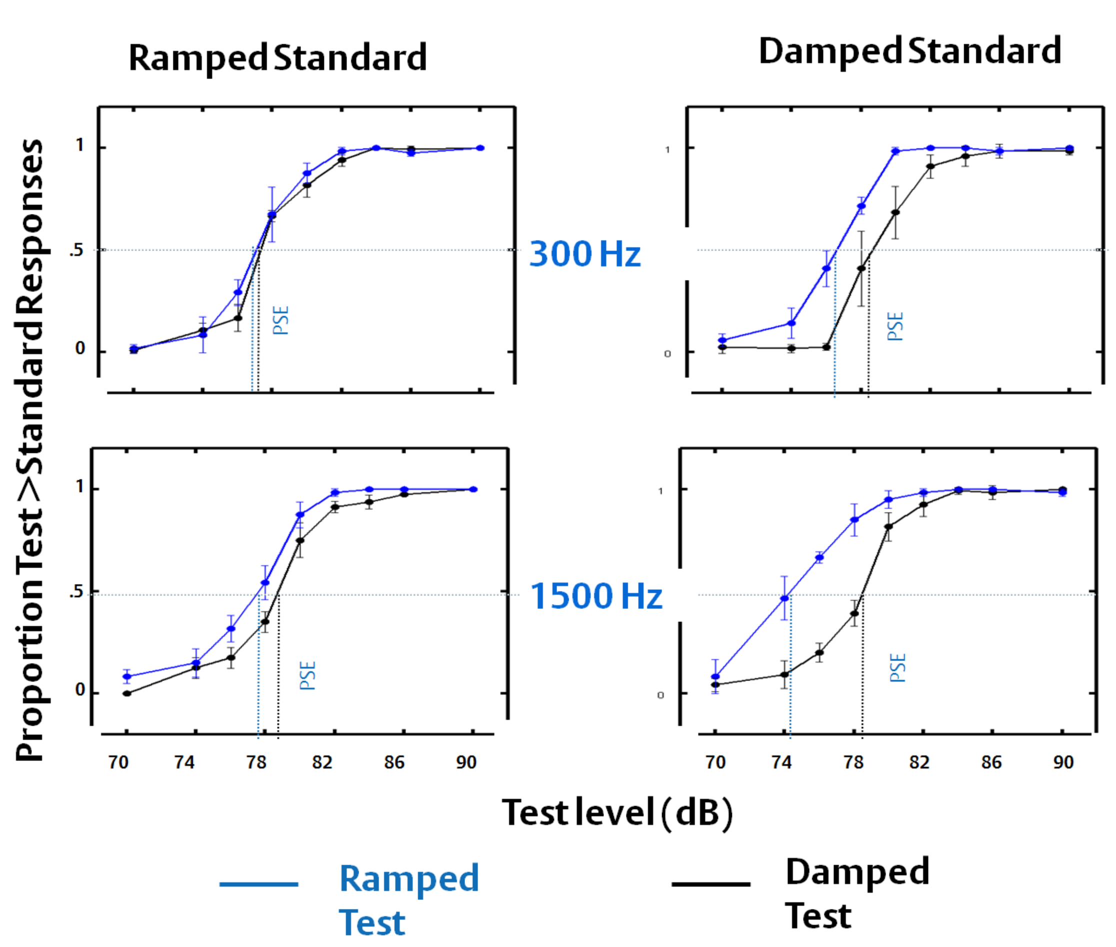

Fig 7. Proportions of trials where listeners responded that the test sound was louder than the standard sound (4 listeners, 120 observations per point). On the left; loudness functions for the RIR ramped with ramped pairings and the RIR ramped with damped pairings, in the 300 Hz and 1500 Hz conditions. On the right, the corresponding functions for the RIR damped with damped pairing and RIR damped with ramped pairings. Vertical lines show 'Points of Subjective Equality' (PSEs) where loudness is equal. PSEs for damped with damped are to the right of the others, indicating that these test sounds are the quietest.

Loudness context effect; same-frequency results

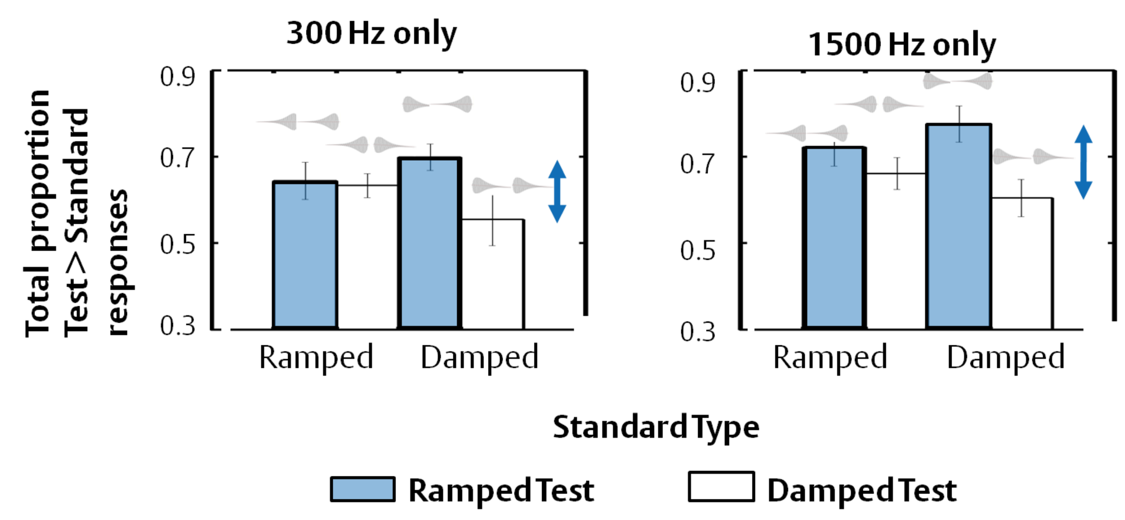

Fig 8. Total proportion of trials where listeners responded that the test sound was louder than the standard sound, pooled across all 9 test sound levels and averaged across the 4 listeners. The loudness context effect is indicated with blue arrows. Error bars show standard deviation.

Envelope-order is important. There is a significant 2-way interaction between standard envelope and test envelope (F(,)= ; p < 0.001).

Cross-frequency results

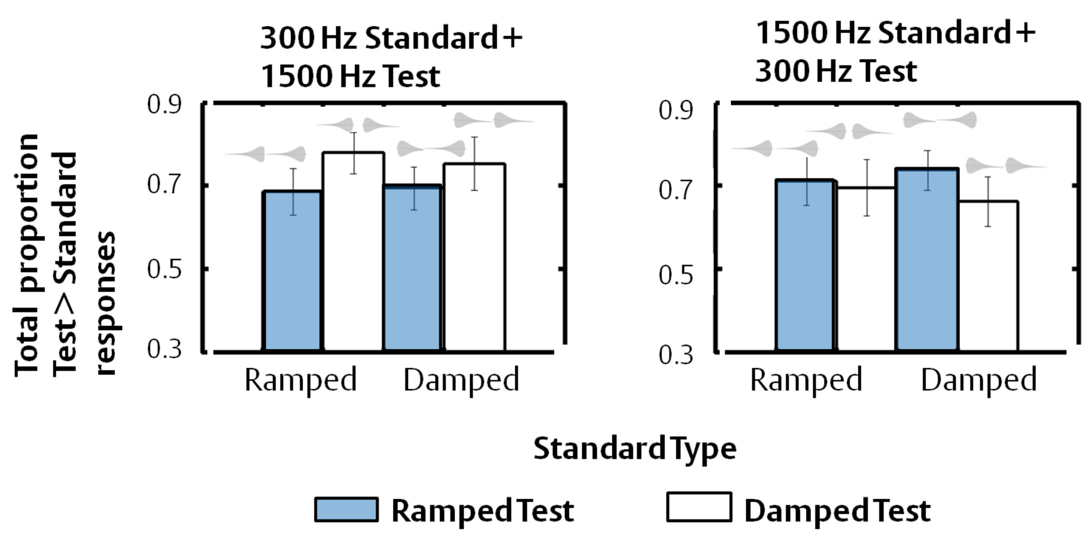

Fig 9. Total proportion of trials where listeners responded that the test sound was louder than the standard sound. The loudness context effect no longer remains. Error bars show standard deviation.

When standard and test sounds occupy different frequency regions, the loudness context effect disappears. The 3-way interaction between standard envelope x test envelope x same-vs cross-frequency is significant [F(,)= ; p<0.002].

Conclusions

The loudness difference and loudness context effects reported earlier remain prominent for both sounds at 300 Hz and for sounds at 1500 Hz.

With cross-frequency standard and test sounds, the loudness context effects disappear. For this form of perceptual constancy to occur, standard sounds and test sounds must occupy the same frequency region.

The result-pattern resembles those from perceptual 'constancy' experiments using reverberant speech (Watkins, 2005; Watkins & Makin, 2007). The findings reported here are consistent with the idea that perceptual constancy for reverberation operates on a frequency-band-by-band basis.

References

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Acknowledgements

Supported by EPSRC.