Objective assessment of concert hall acoustics

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Objective measures for concert hall acoustics

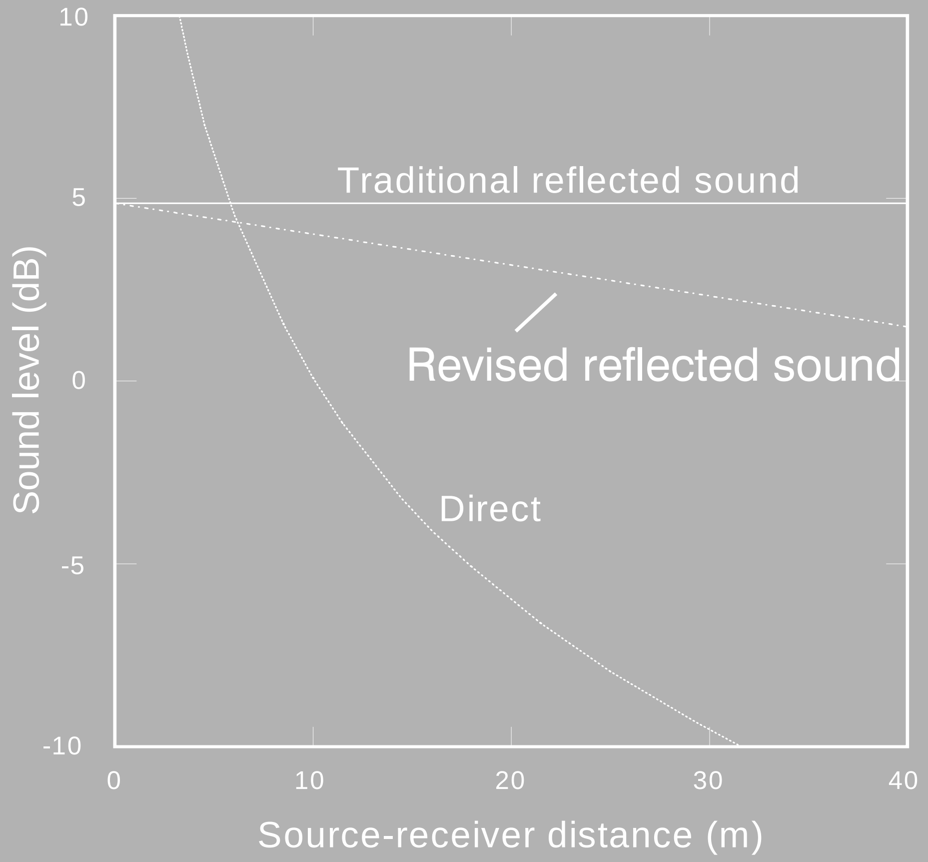
- Can be used by people with NO knowledge of subjective issues!
- Except for reverberation time, average values for a hall need to be treated carefully, especially in the case of total level G.
- Are used (inappropriately?) for spaces other than those for unamplified music

Measure	Acceptable range
Reverberation time (RT)	$1.8 \leq RT \leq 2.2$ seconds
Early Decay time (EDT)	$1.8 \leq EDT \leq 2.2$ seconds
Early-to-late sound index (C_{80})	$-2 \leq C_{80} \leq +2$ dB
Early lateral energy fraction (LF)	$0.1 \leq LF \leq 0.35$
Total relative sound level (G)	$G > 0$ dB

Recommended ranges for objective measures for concert halls (at mid-frequencies)

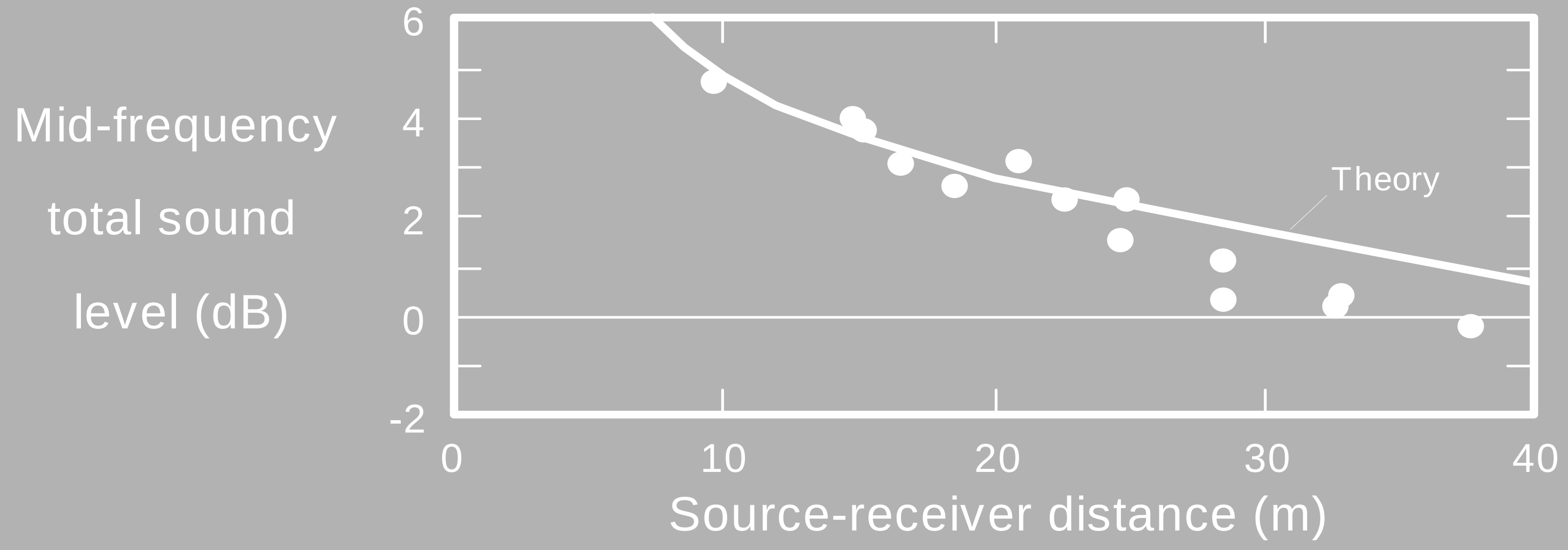
Assessment relative to revised theory of sound level

Revised theory is based on the observation that total sound level in concert auditoria does not behave according to traditional theory. This behaviour is also found in a fully diffuse space.



Behaviour of sound level G in a room

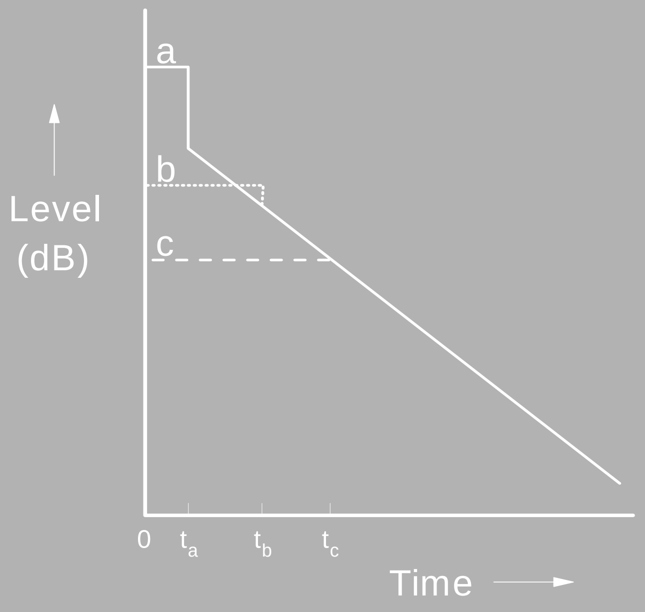
Sound level behaviour in a typical large concert hall



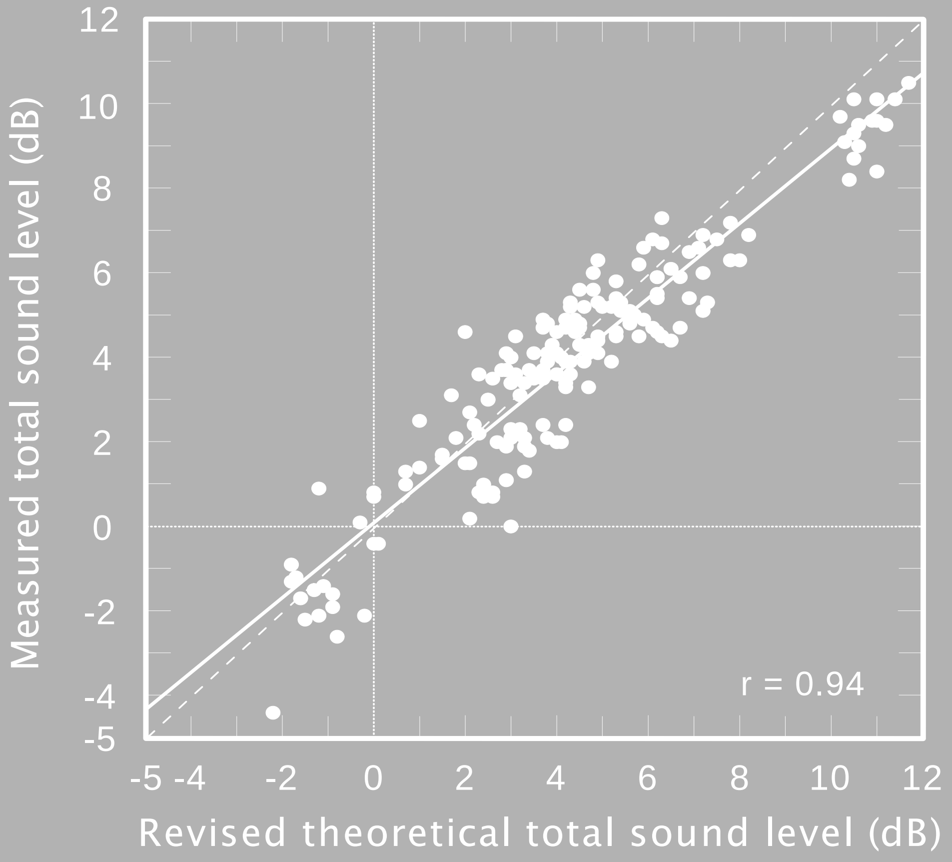
Revised equation for reflected sound level

$$L_{refl} = \overset{\text{Traditional theory}}{10 . \log\left(\frac{31200 . T}{V}\right)} - \overset{\text{‘Slope’}}{\frac{0 \cdot 174 . r}{T}} \quad \text{dB}$$

Note, slope is an inverse function of reverberation time



Assumed integrated decays with revised theory



Measured vs. revised theoretical sound level

Mid-frequency values without overhung locations

Subdivision of the total sound

If e is the early energy and l is the late component, then

$$G = 10.\log (e + l) \text{ and } C_{80} = 10.\log (e/l)$$

So from measurements of G and C_{80}, the early and late level can be derived ($E = 10.\log e$ and $L = 10.\log l$)

Revised theory can also be used to predict the early and late components

Note: measurements reported below have the source on centre line, 3 m from front stage front, so no stage floor reflections

The ‘new’ analysis technique involves comparison of the early, late, total and early-to-late index with revised theory predictions

Proposed graphs for temporal energy analysis

dB

Early (10.log e)

Source-receiver distance (m)

dB

Late (10.log l)

Source-receiver distance (m)

dB

Total (10.log (e + l))

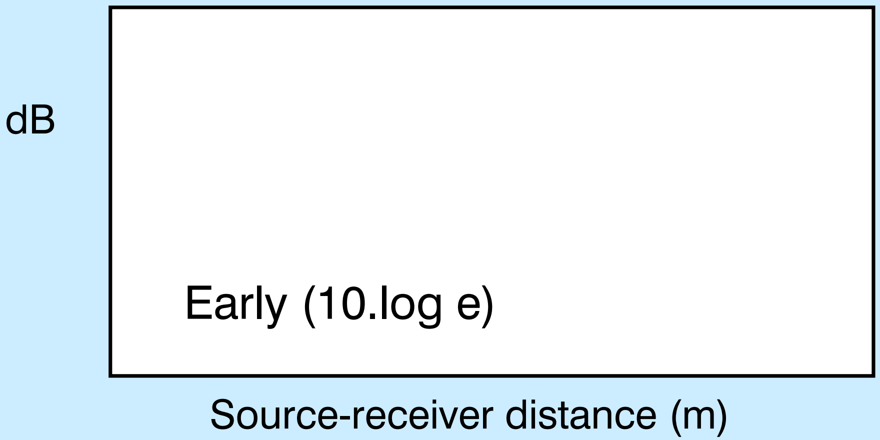
Source-receiver distance (m)

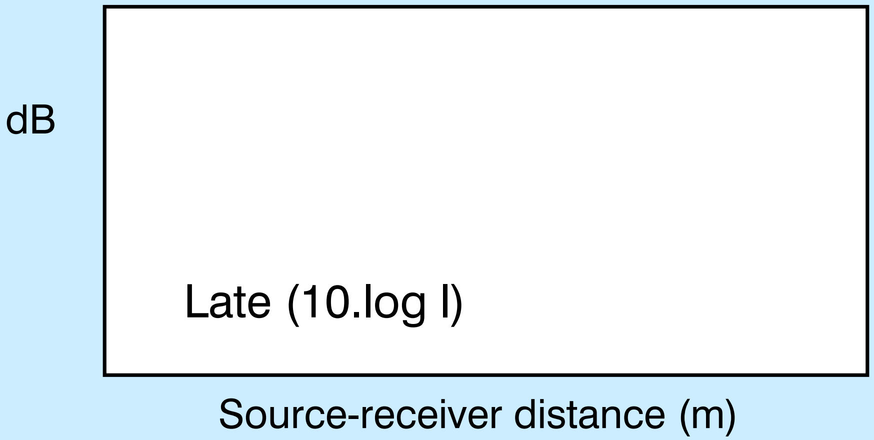
dB

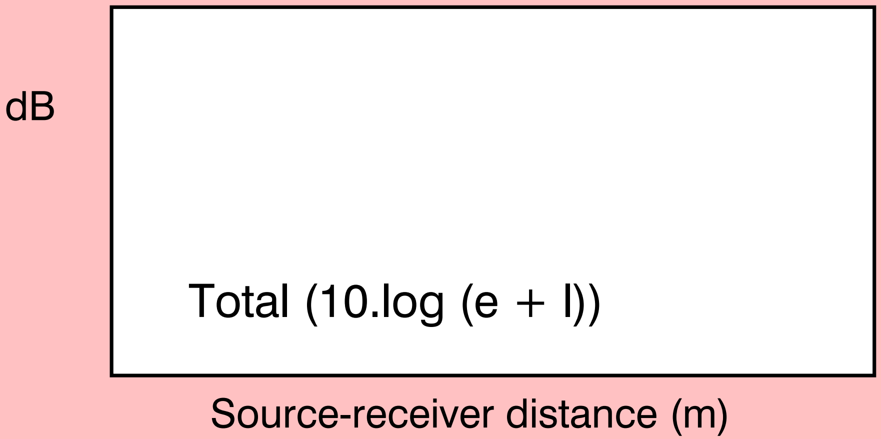
C_{80} (10.log e/l)

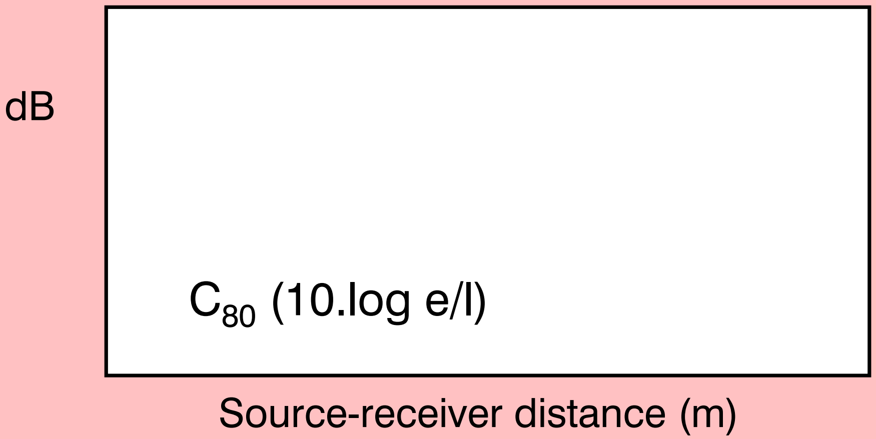
Source-receiver distance (m)

Objective behaviour influenced by auditorium geometry









Subjective quantities

Determinants of objective behaviour

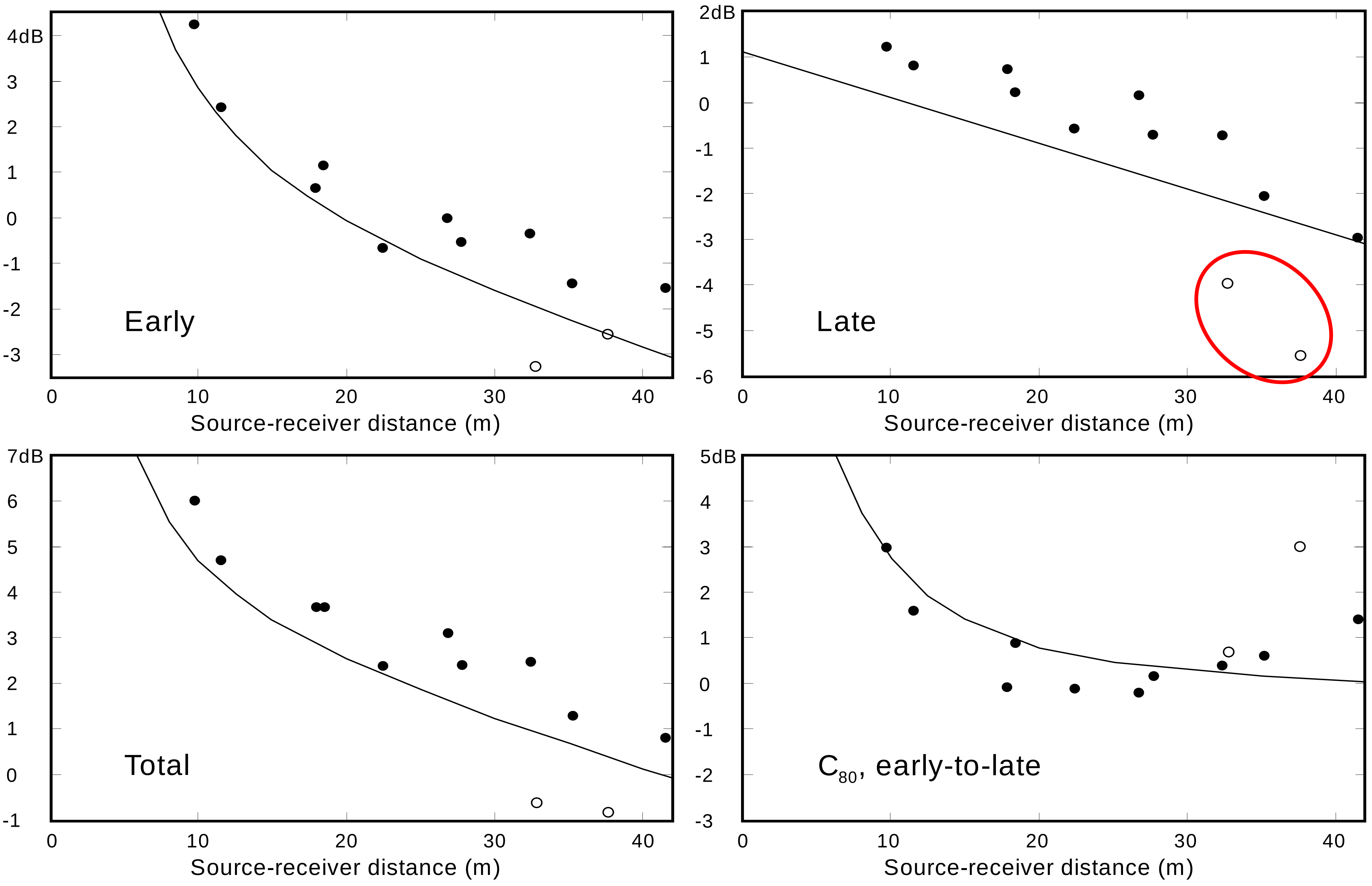
Early sound – direct + early reflections

Late sound – access to reverberant sound

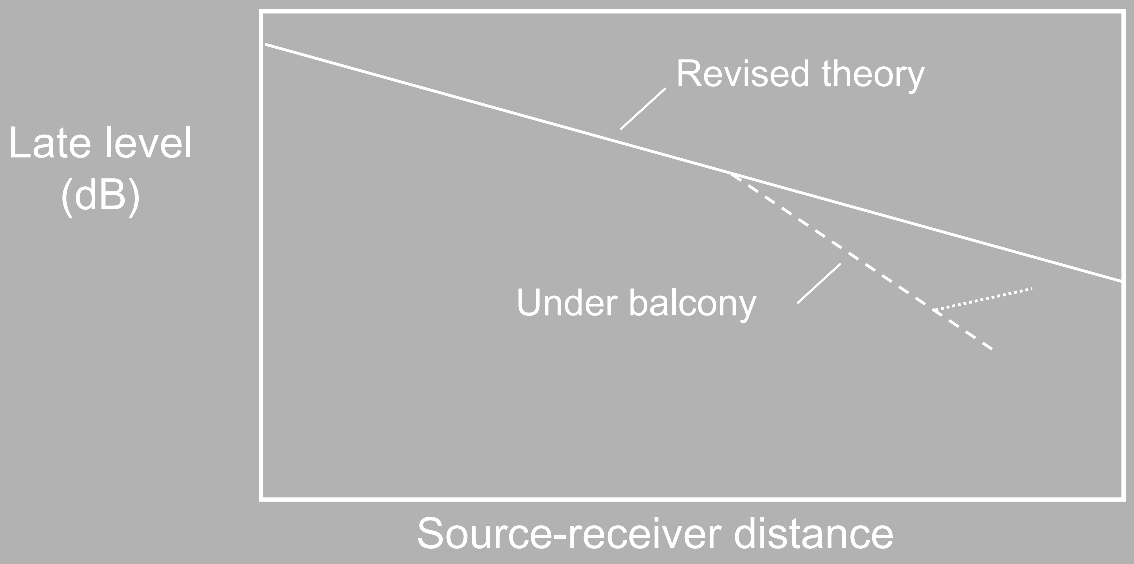
Note that RT and volume <u>are included</u> in the prediction

For assessment of G and C_{80}, correction for RT change is necessary when measurements have been made in an unoccupied concert hall

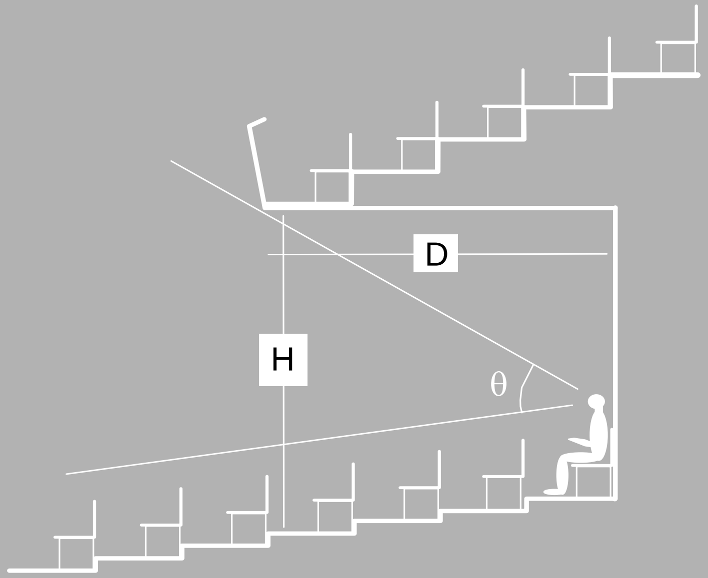
Royal Festival Hall, London (unoccupied, 1982)



Sound behaviour under balcony overhangs

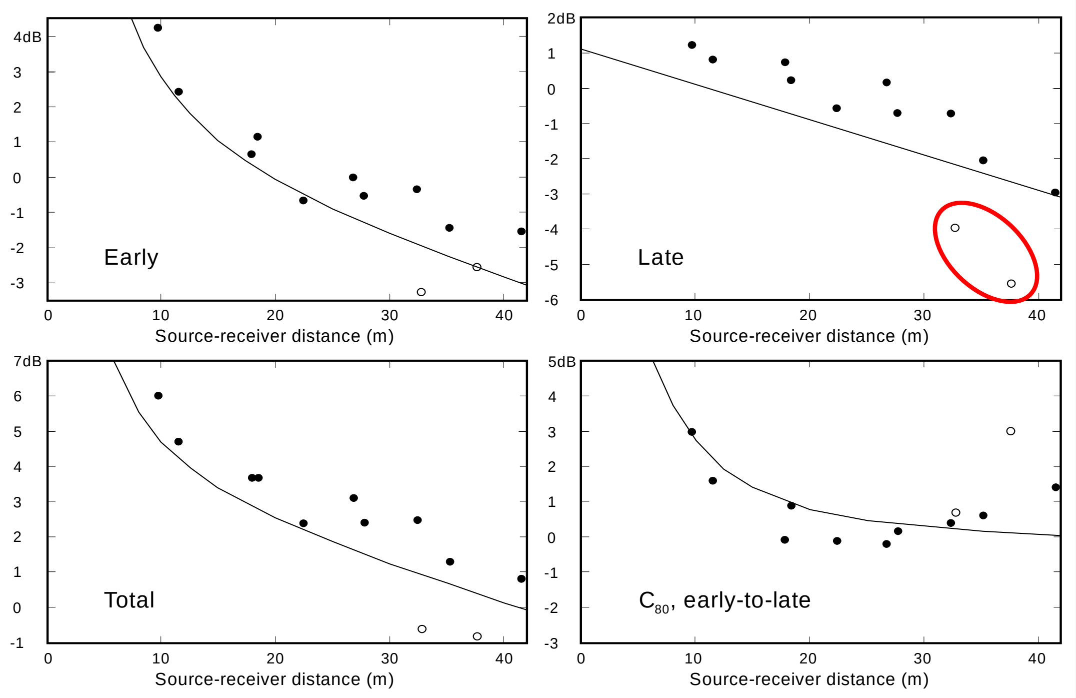


Major effect is on late sound



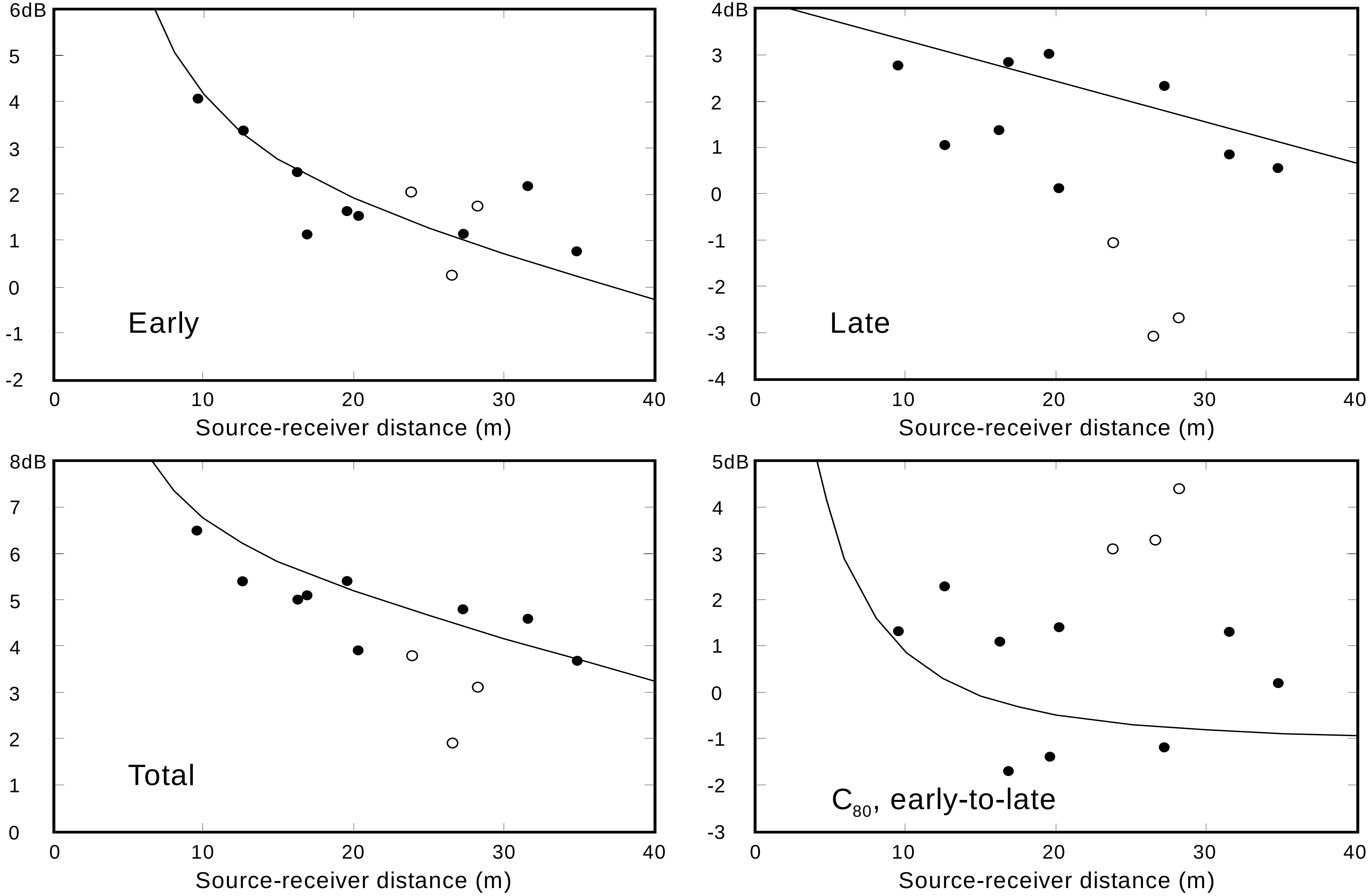
Overhang effect is linked to vertical angle of view, θ

Royal Festival Hall, London (unoccupied, 1982)



Objective behaviour in the Festival Hall follows revised theory fairly well except for the late sound at seats below the balcony overhang

Colston Hall, Bristol (unoccupied, 1982)



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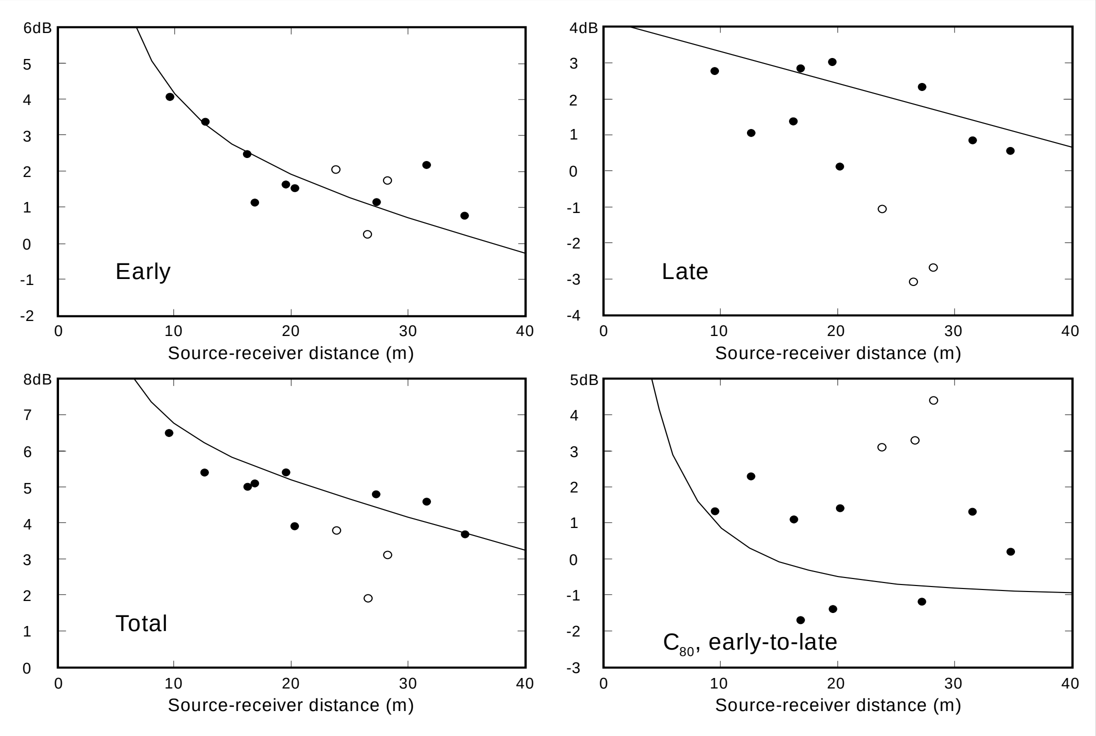
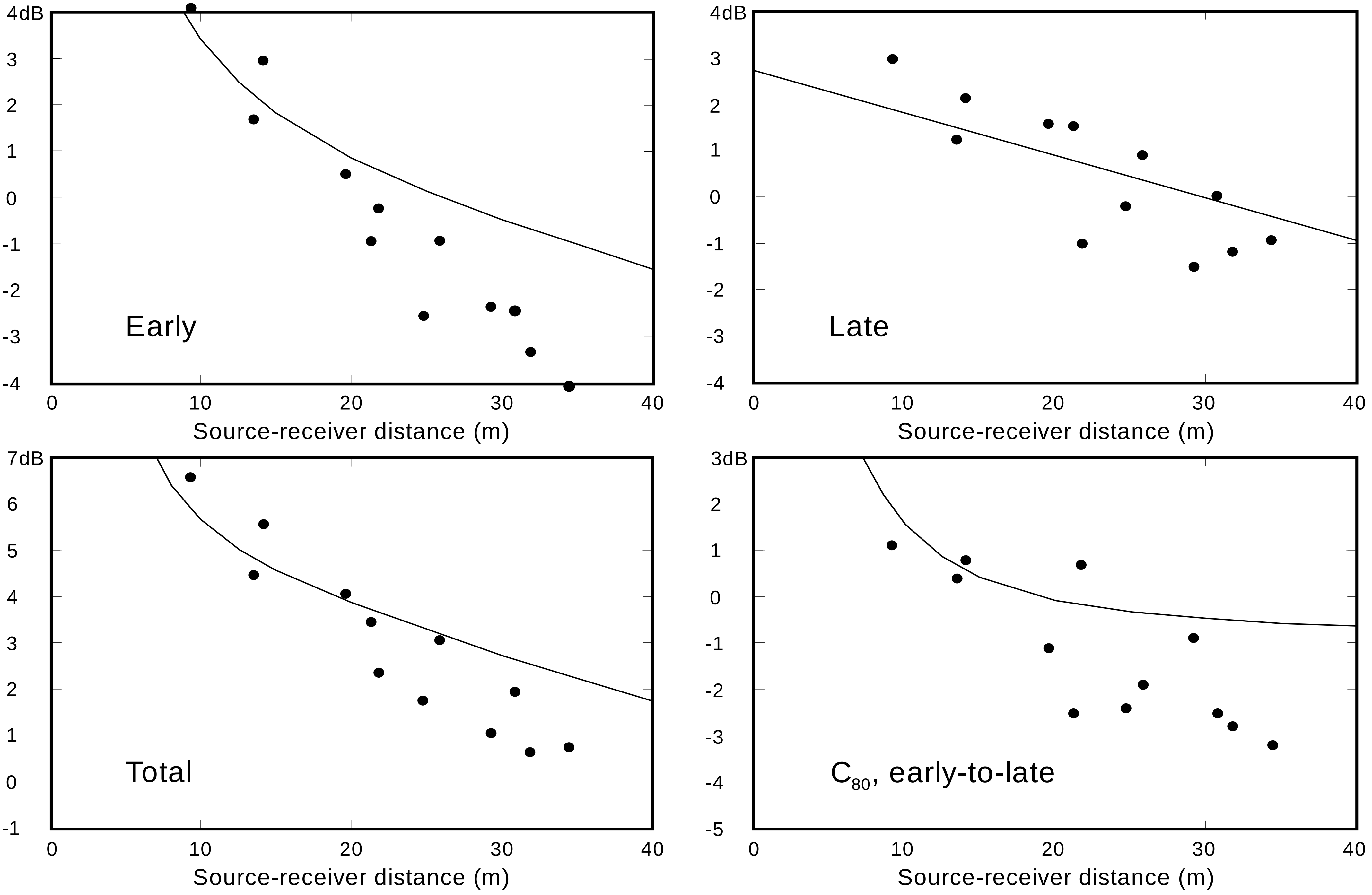


Major effect on late sound caused by balcony overhang subdividing the room vertically

Very wide range of C_{80}

Barbican Concert Hall, London (unoccupied, 1984)



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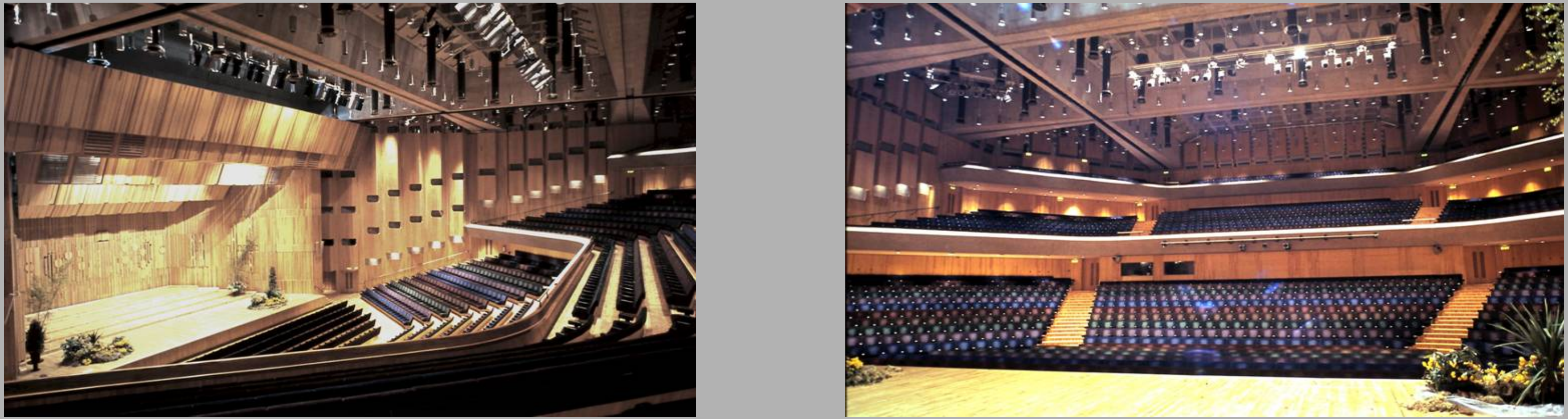
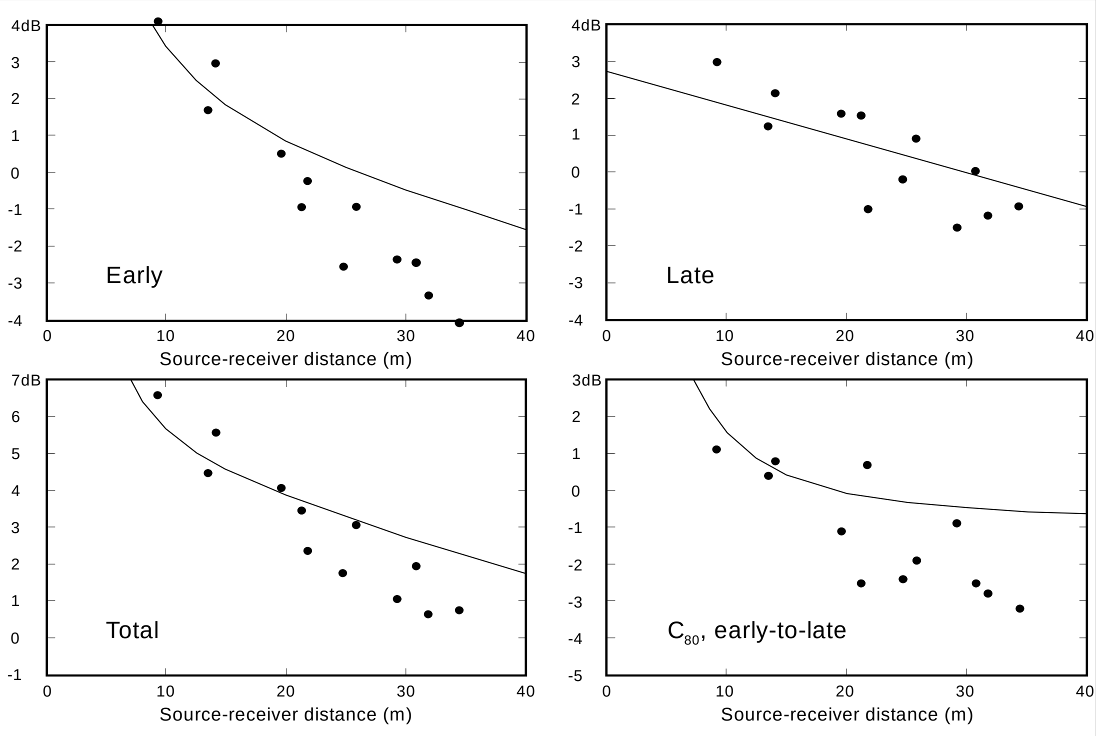
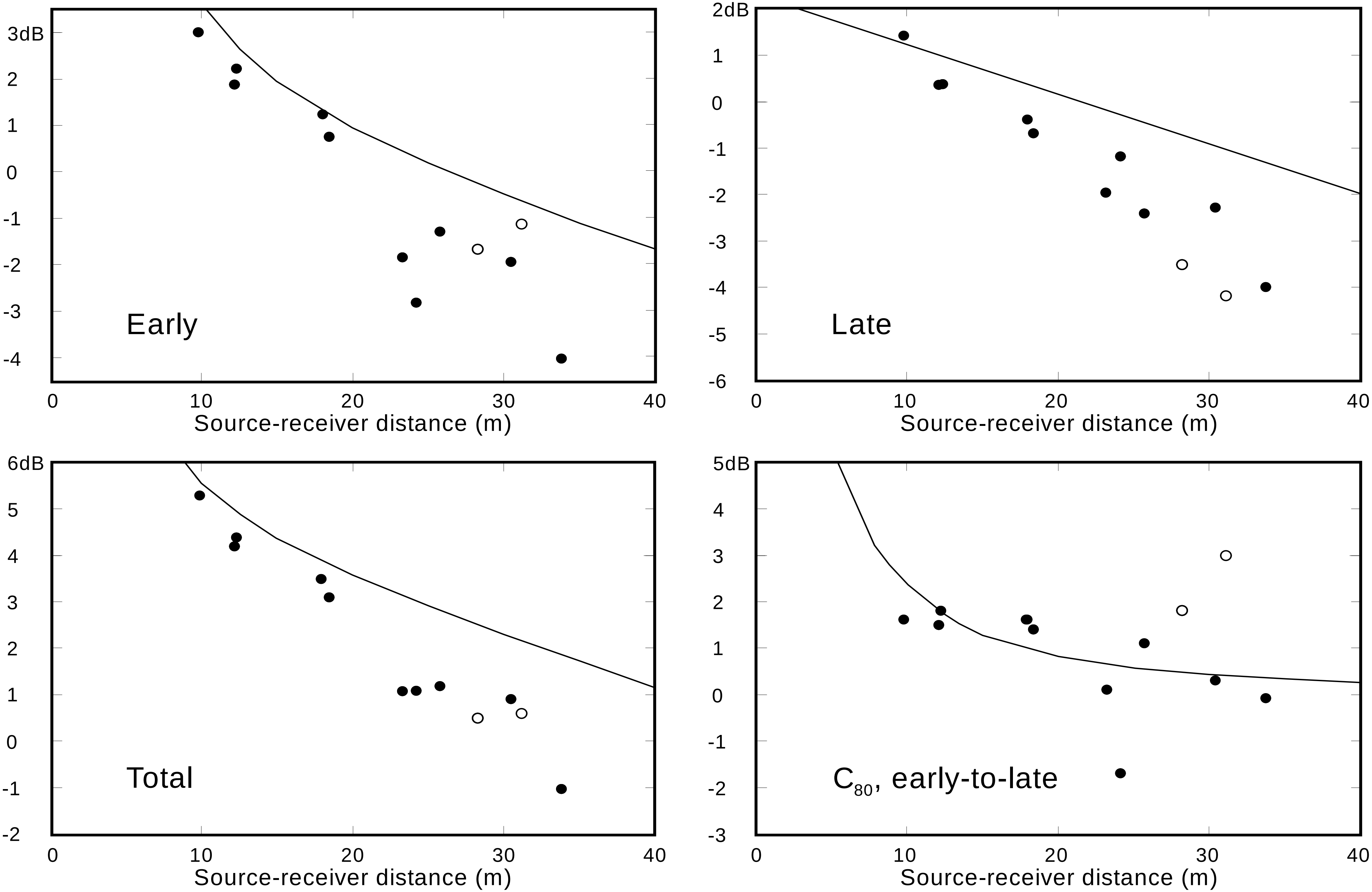


Low early sound levels result in quiet sound and poor clarity in remote seats

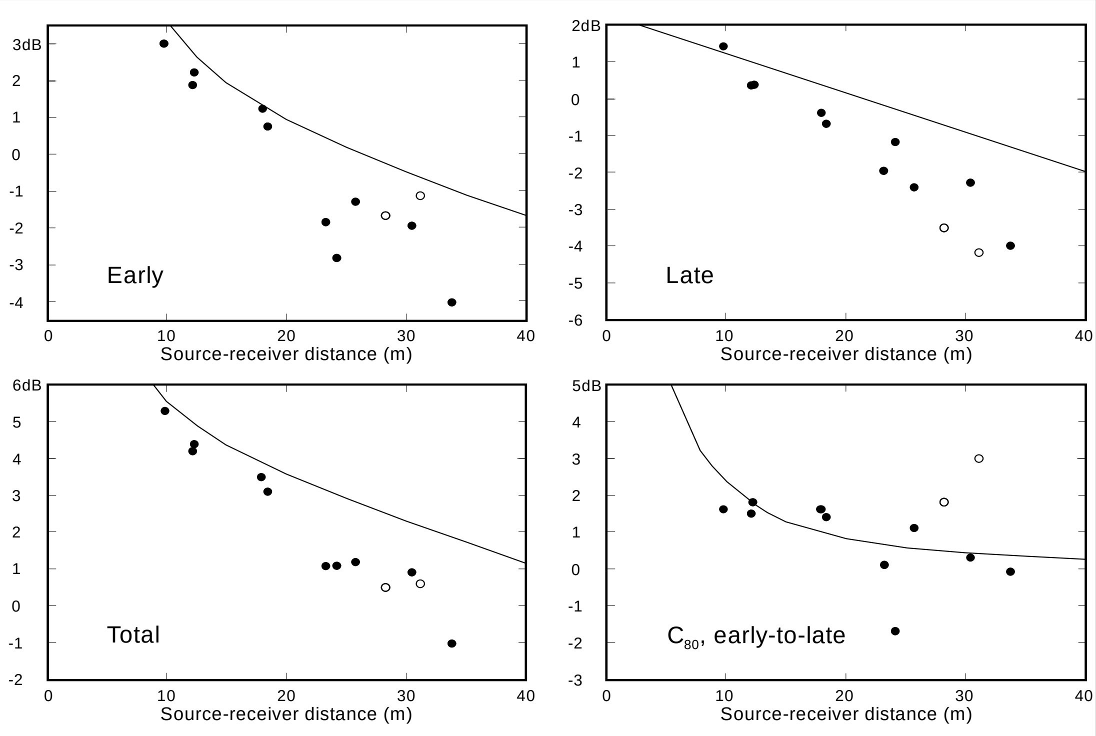


Fairfield Hall, Croydon ('occupied', 1982)



Fairfield Hall, Croydon (‘occupied’, 1982)

At remote seats, low early and low late sound levels result in quiet sound towards the rear of the hall



CONCLUSIONS

This analysis provides valuable insights into the interplay between geometrical design of concert halls and the acoustic consequences.

Each concert hall has its story to tell.

Temporal energy analysis offers insights into the following:

- Overall geometrical design
- Balcony design
- Causes of high or low sound levels and objective clarity, C80
- Uniformity of response
- Comparison with average behaviour for volume and RT

Beware: agreement with revised theory is not necessarily the optimum

Temporal Energy DIstribution Analysis

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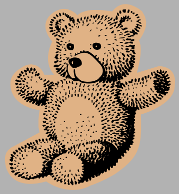
TEDIA ? (tedium)

or

TEDI Analysis



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