

Background



Face masks: act as a low-pass acoustic filter on speech (e.g., Corey et al., 2020) & may negatively impact speech **intelligibility** & listener **effort**, especially in noise (e.g., Toscano & Toscano, 2021; Brown et al., 2021).

Face shields: attenuate high frequencies but may amplify low frequencies (Corey et al., 2020), distorting the acoustic signal. Possible negative impact on intelligibility (Rudge et al., 2020).

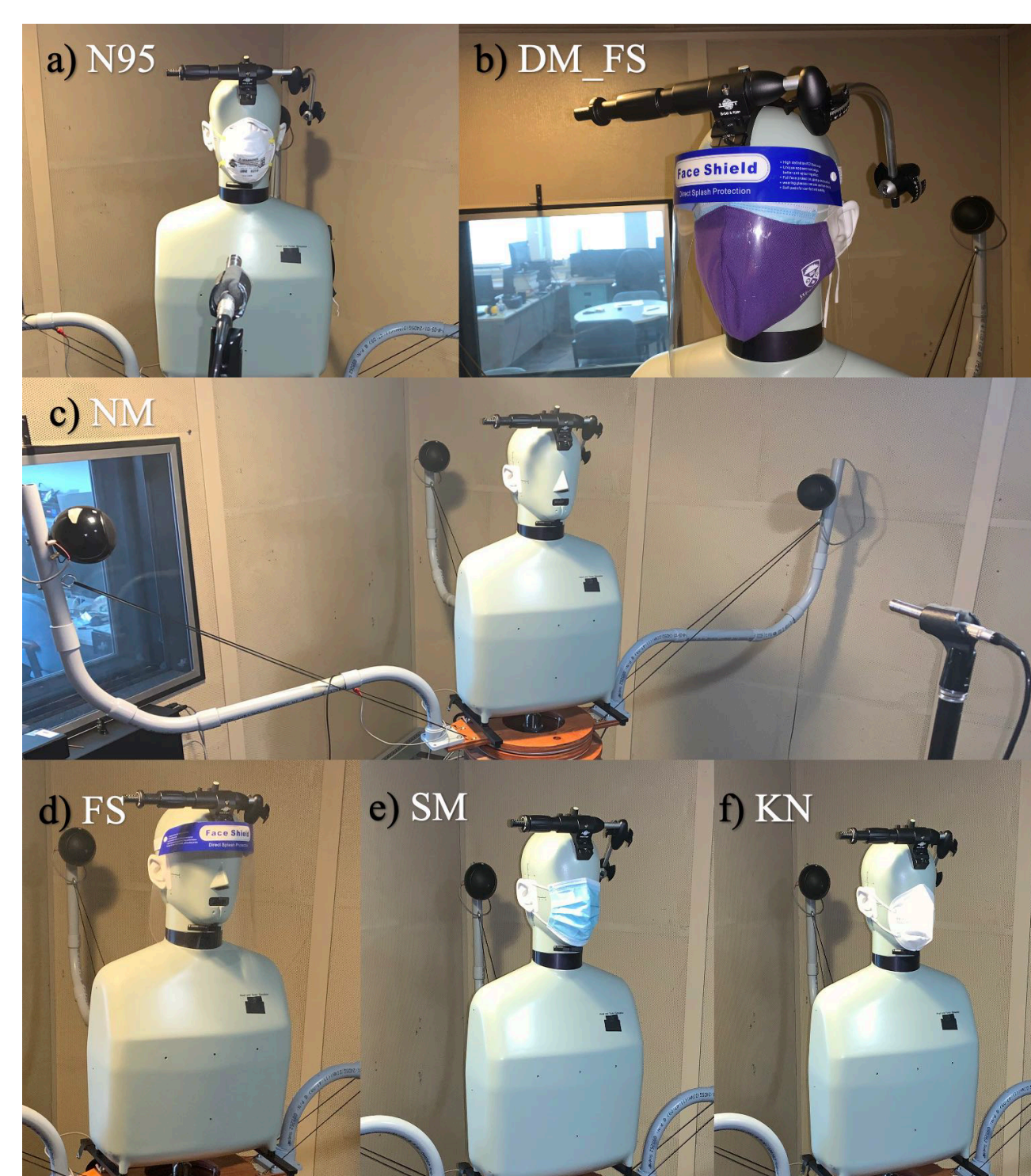
Purpose

Quantify the effect of 12 face masks & shield combinations on:

- 1) Speech intelligibility
- 2) Perceived listener effort
- 3) Spectral speech acoustics

Methods

Audio Recording Procedure



Recording setup: HATS donning different face mask & shield combinations.

Perceptual Task Procedure

Stimuli: 10 sentences per mask condition in Noise

Listeners: 78 listeners recruited via Prolific crowdsourcing platform.

- Ages 18-34. 46 female, 16 male, 2 genderqueer.
- Each listener heard 5 sentences from 5 mask conditions (+/- shield) in multitalker noise (following a practice block).
- At least 7 listeners heard each stimulus.
- 5 listeners removed for falling < 1.5 SD below mean accuracy.

Task:

1. **Transcribe exactly what you hear**
 - keyword accuracy as % correct
2. **Rate how effortful the speech was to understand**
 - visual analog scale listener effort (low to high)

Analysis

Acoustic outcomes

- Extracted from **Quiet** condition
- **Maximum energy (dB)** in 3 ranges from long-term average spectrum:
 - Low (0 – 1 kHz)
 - Mid (1 – 3 kHz)
 - High (3 – 8 kHz)
- **Mean utterance intensity (dB)**

Perceptual outcomes:

- Keyword accuracy
- Listener effort

Statistical analysis

- Linear mixed effects models

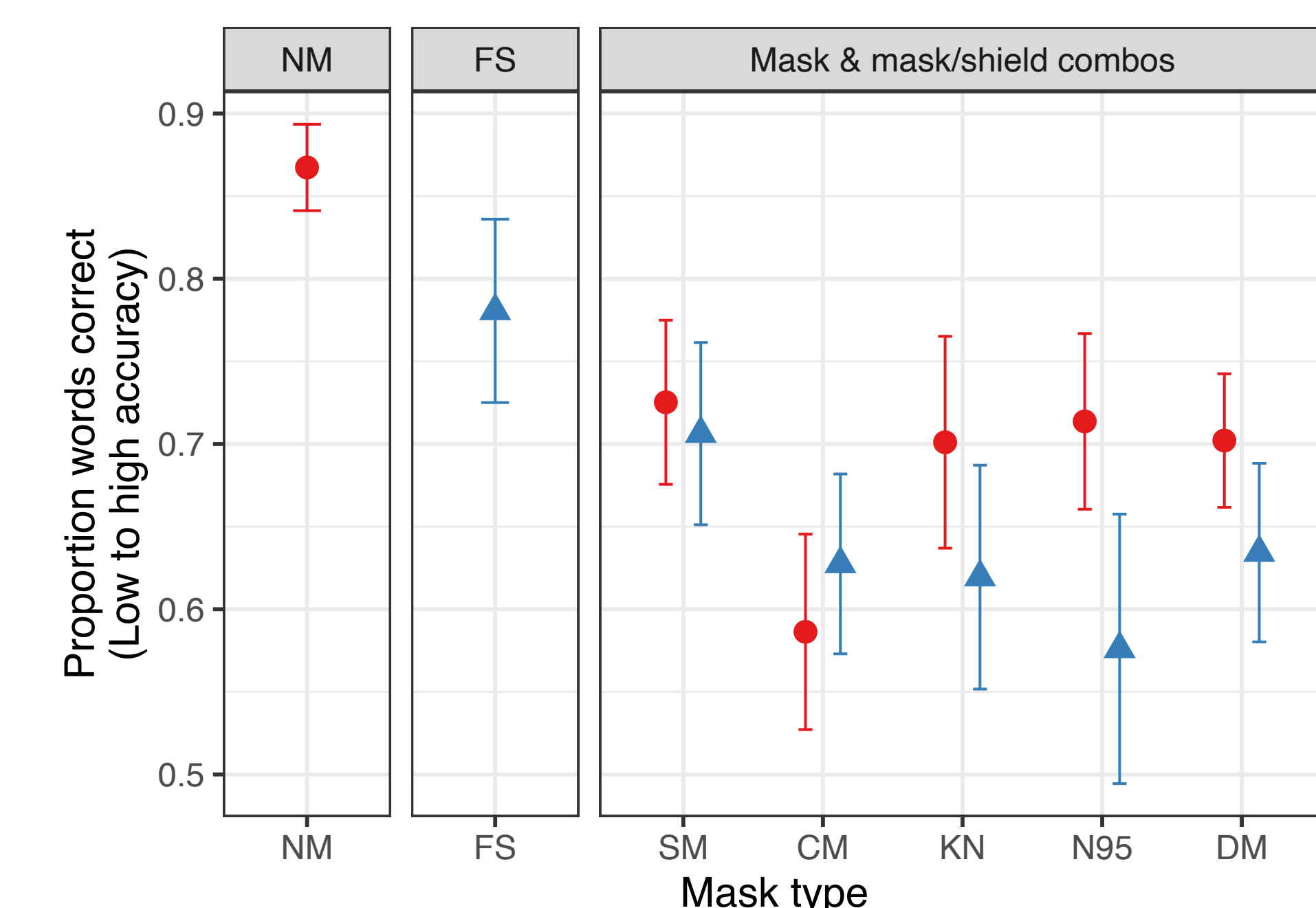
$$[Accuracy/Effort] \sim \text{mask type} * \text{shield} + \text{talker} + \dots$$
- Repeated measures correlation

$$[Acoustic outcomes] \sim \text{mask type} * \text{shield} + \text{talker} + \dots$$
- Accuracy ~ Effort

Noise: Played in 5dB SNR multi-talker noise & in quiet

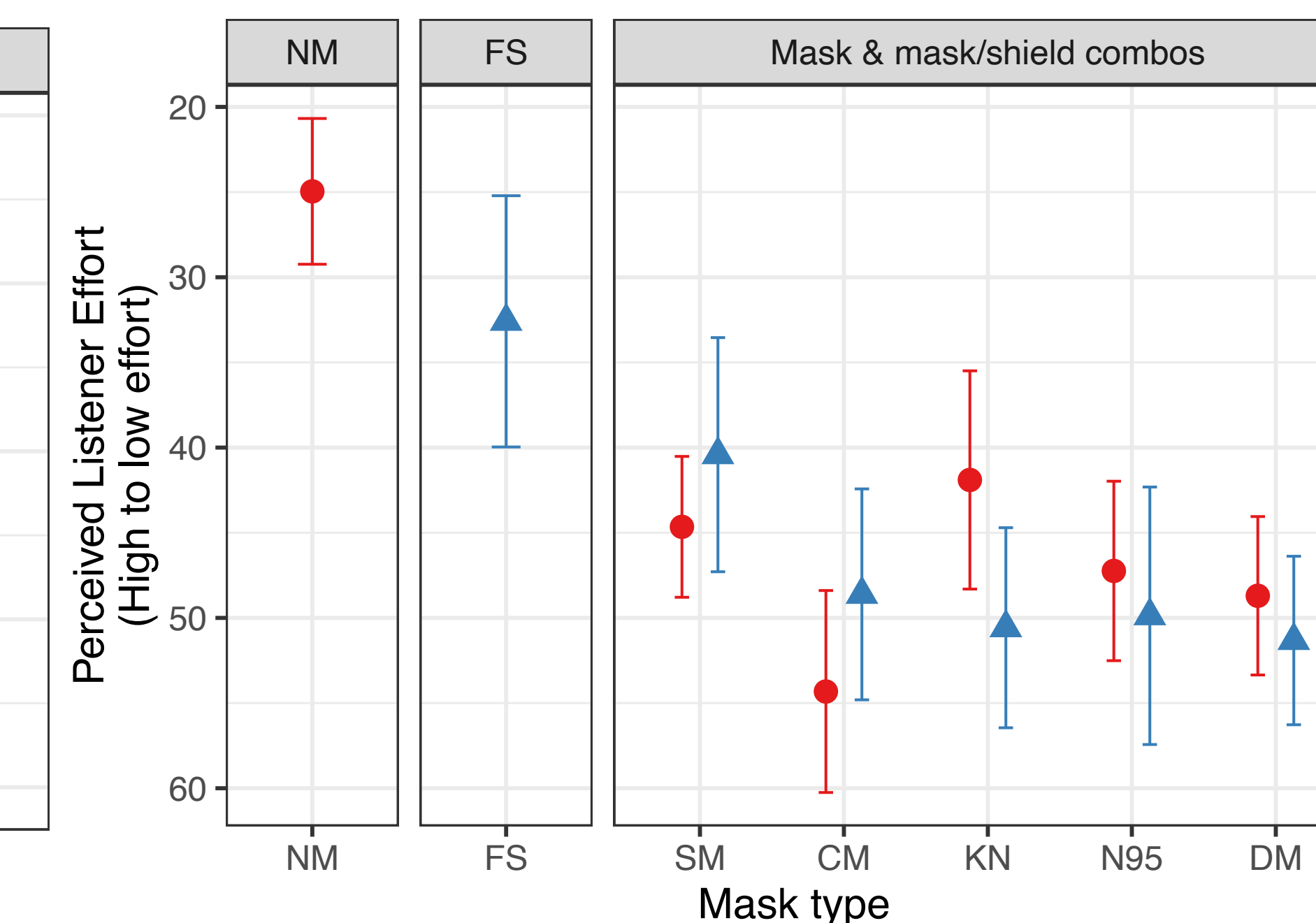
Results & Discussion

1. Speech Intelligibility



🔴 mask only 🔵 + face shield

2. Listener Effort



Accuracy and Effort ~ Mask

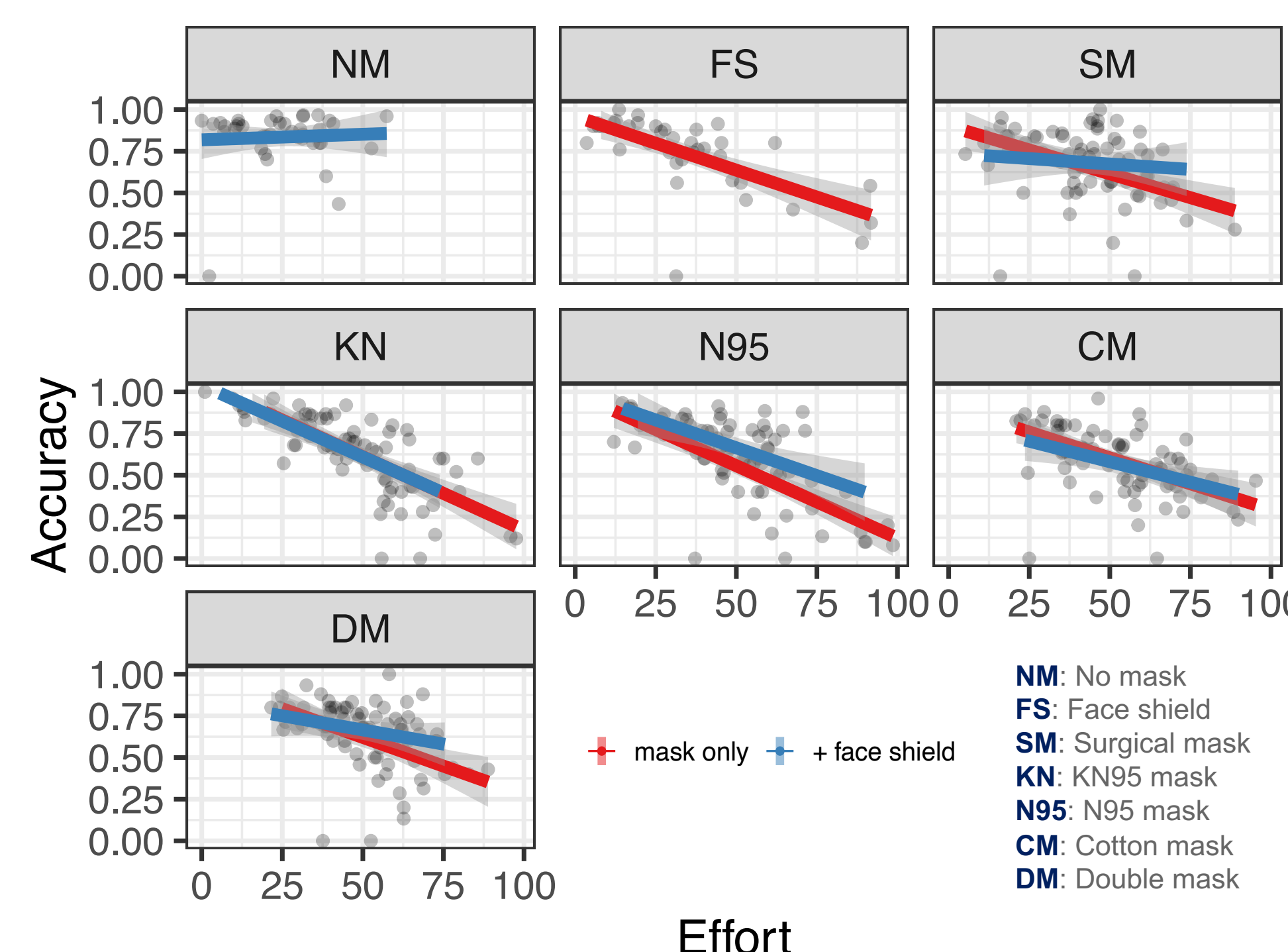
- **All masks associated with reduced accuracy & increased effort** (med to large effect sizes).

- Exception: No differences observed for the face shield on its own.

- **Overall, layering the shield was associated with further reductions in accuracy** (small effect size) **but did not impact effort.**

Accuracy ~ Effort

- **Strongly correlated overall:** $r = -0.79$; $p < 0.001$



Conclusions

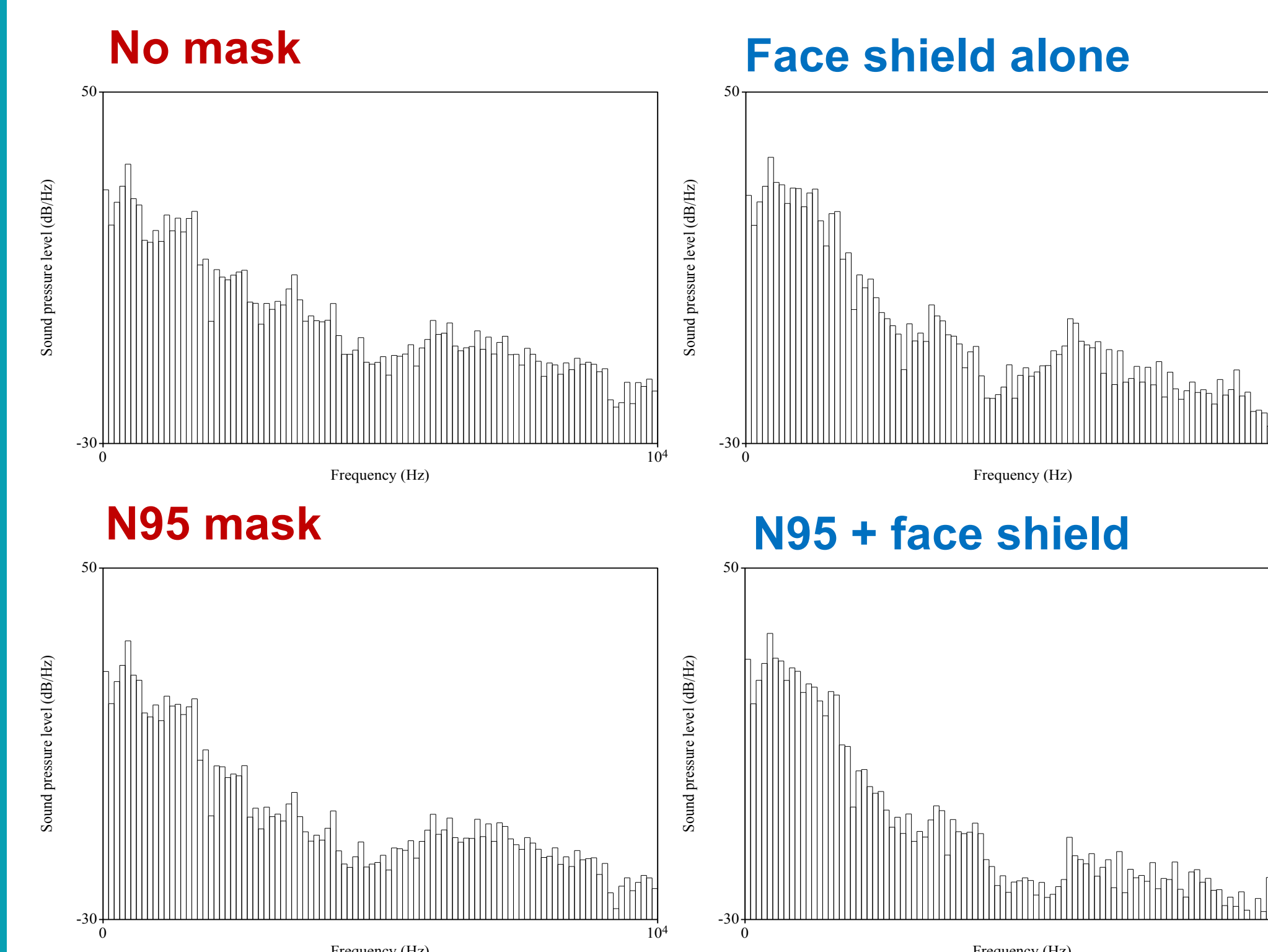
- **Surgical masks:** little reduction in spoken communication (even with shield)
- **Cotton masks:** greatest impact
- **N95 + shield:** worst combination
- Listeners were less accurate and reported greater effort for all face masks & mask/shield combinations.
 - But not affected by shield alone
- The shield amplified low- to mid-frequency energy and attenuated high frequencies.
- Layering masks with a shield resulted in poorer listener accuracy, but not with increased effort over and above the effects of the masks.

3. Spectral Acoustics

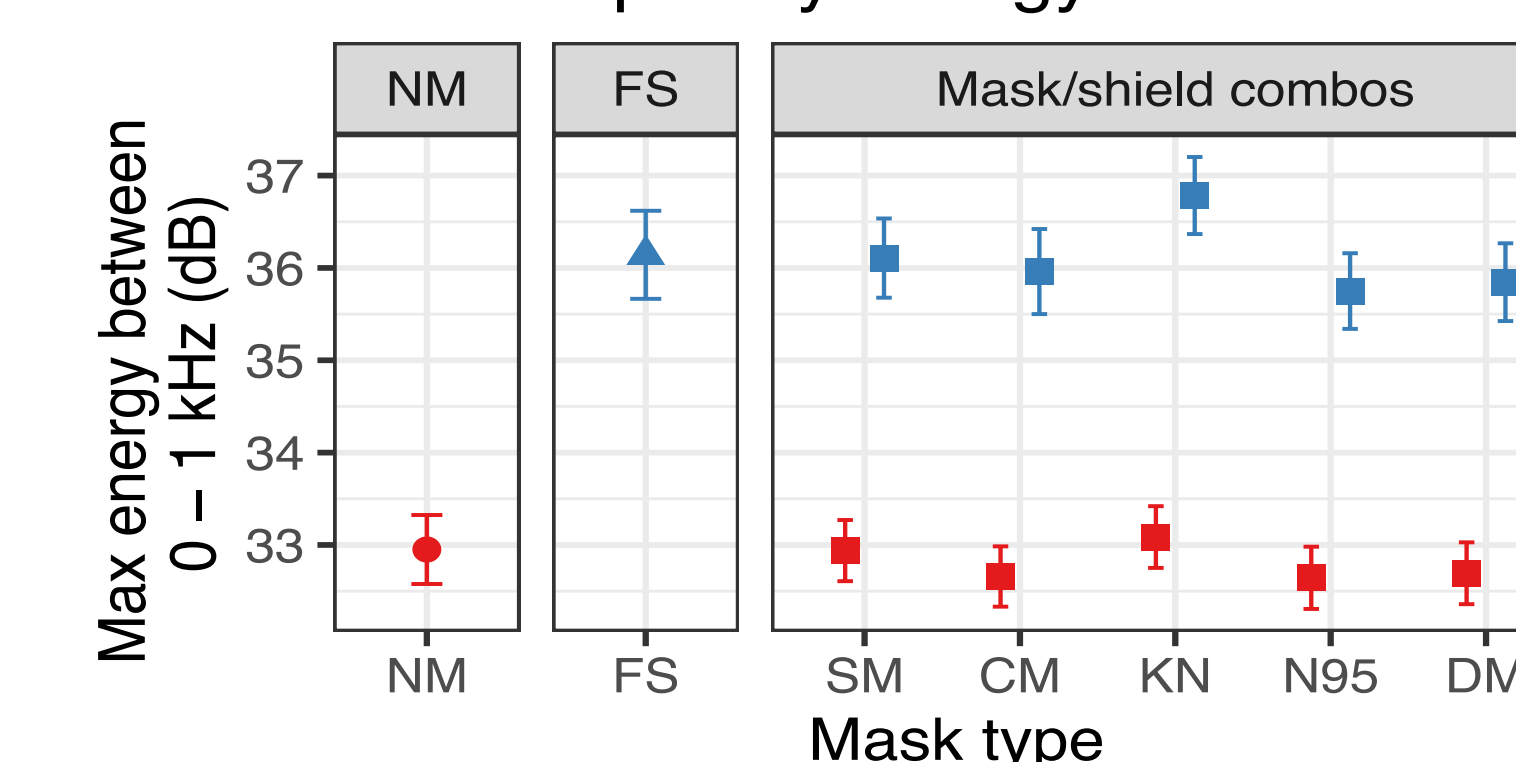
Acoustic Measures ~ Mask

- **Low:** No effect of mask. Amplified by shield.
- **Mid:** Reduction for all masks *except* surgical (small to large effect sizes). Amplified by shield (large effect size).
- **High:** Reduction for all masks & shield
- **Intensity:** Reduced (<0.5 dB) for all masks *except* surgical mask. Amplified (3-5 dB) by the face shield

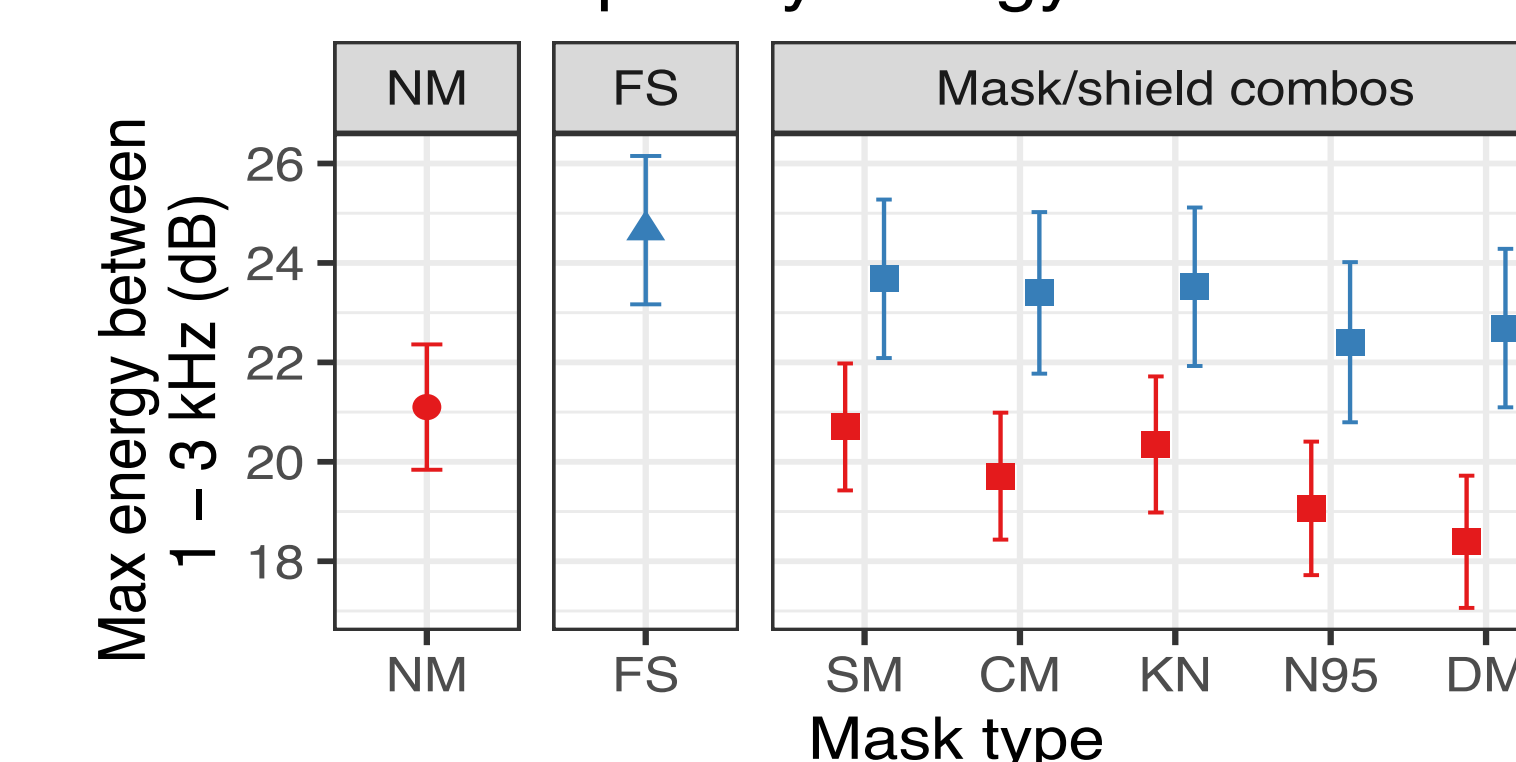
Example spectra



Low frequency energy



Mid frequency energy



High frequency energy

