Cross-Modal Matching and Internal References

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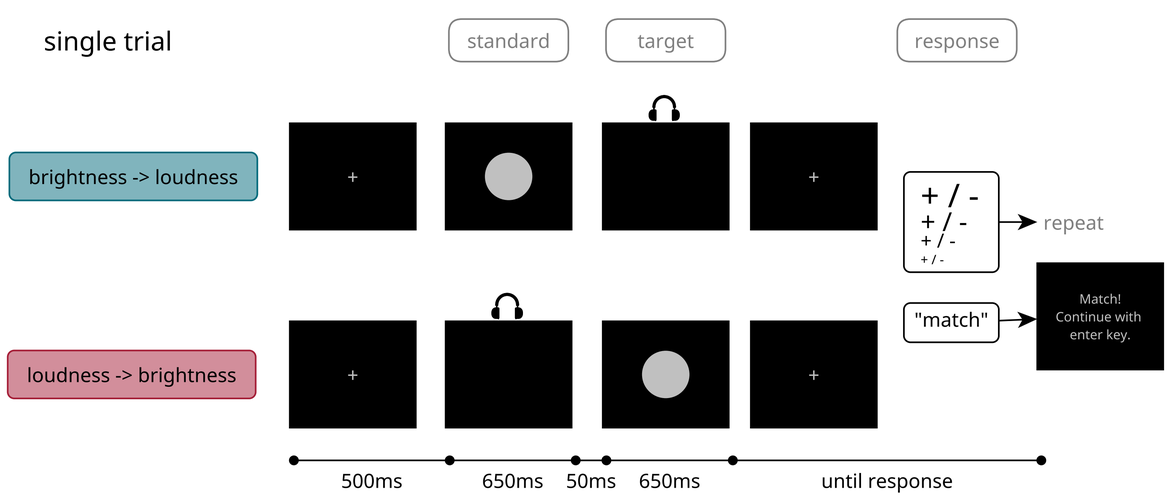
Matching Task

'Make the light as bright as the sound is loud.'

We are not only able to compare intensities within modalities across different stimuli, like the brightness of lights differing in hue, or the loudness of sounds differing in pitch, but also between modalities: the brightness of light and the loudness of sound.



Stimuli

Visual stimuli are grey circles on black background with diameter $4°$ visual angle and luminance range: $67.6 - 93.1$ dB re 10^{-10} lambert. Acoustic stimuli are pink noise bursts in the range of $20 - 80$ dB SPL.

Procedure

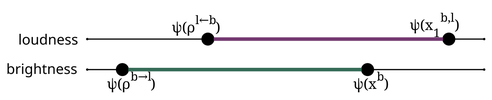
The subject varies the respective target stimulus intensity by pressing a key until satisfied.

Theoretical Background

Cross-dimensional Representation

(Heller, 2021; Luce et al., 2010)

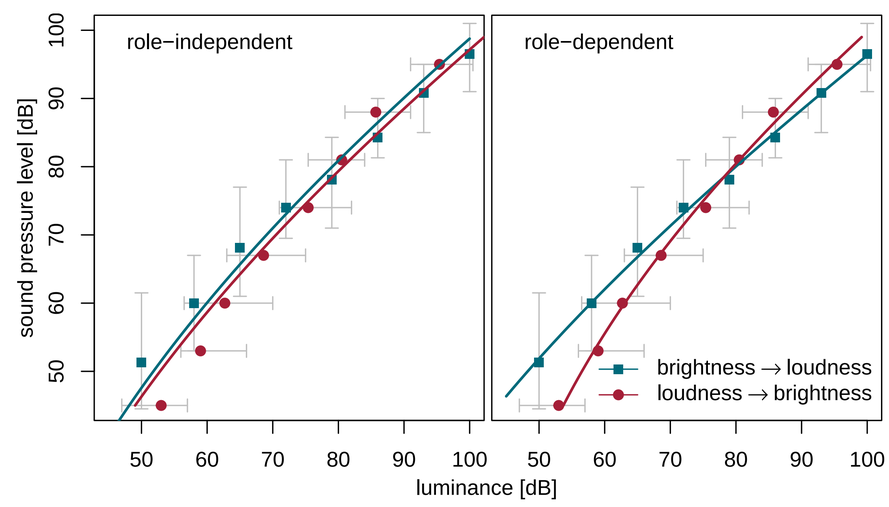
$$\psi_l(x_1^{b,l}) - \psi_l(\rho^{l \leftarrow b}) = W(1) \cdot \left(\psi_b(x^b) - \psi_b(\rho^{b \rightarrow l})\right)$$



- $x_1^{l,b}$ adjusted stimulus level, e. g. luminance of visual stimulus
- $\rho^{b \leftarrow l}$ reference level on variable dimension
- ψ_l and ψ_b psychophysical functions; here $\psi_l(x) = \alpha_l x^{\beta_l}$ and $\psi_b(x) = \alpha_b x^{\beta_b}$
- W cognitive weighting function; $W(1)$ is not necessarily 1.
- x^l stimulus level of standard, e. g. sound pressure level of auditory stimulus
- $\rho^{l \rightarrow b}$ reference level on standard dimension
- 1 adjustment ratio, 'adjust light so that it appears equally intense as sound'

Regression Effect and Model Predictions

- the often-replicated *regression effect* in matching describes, that the stimulus range of the manipulated modality is shortened (Stevens & Marks, 1965)
- do the cross-dimensional matching curves fit the data and predict the *regression effect*?
- are the reference stimuli role-independent, i. e. $\rho_+^{b \leftarrow l} = \rho_+^{b \rightarrow l}$ and $\rho_+^{l \leftarrow b} = \rho_+^{l \rightarrow b}$?



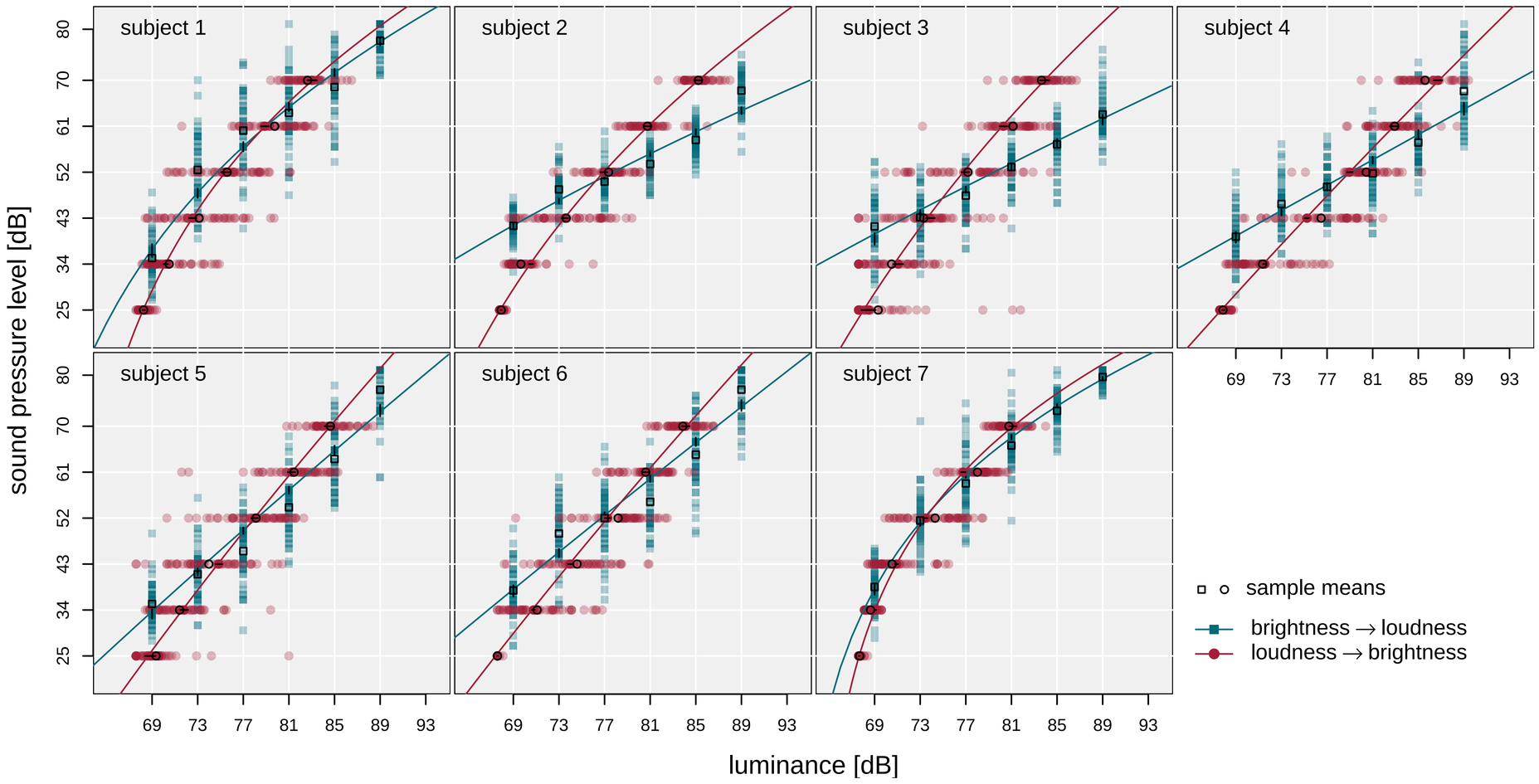
●/ ■ mean matching data from Stevens and Marks (1965) with 10 subjects; bars are inter-quartile ranges)

—/ — matching curves: theoretical predictions (Heller, 2021)

Results

Sample 7 subjects · 6 standards in each modality · 48 matches within 12 experimental blocks · 4 h in two sessions

Matching curves Estimation of model parameters via Bayesian inference with MCMC sampling using theoretically informed priors, and 4 chains with 10000 iterations · in `Stan` (2023)



Conclusions & Work in Progress

- Cross-modal matches on individual level show a shortening of the range of the adjusted stimulus intensity. This replicates the results of Stevens and Marks (1965).
- Individual variability of matches is high.
- Reference stimuli $\rho^{g \leftarrow f}$ and $\rho^{f \rightarrow g}$ cannot be uniquely identified given matching data.
- The matching curve's crossing points indicate reference stimuli magnitudes for which role-independence holds → here in mid-level magnitude.
- Next: experimental setup without matching direction and more experimenter control → no *role*, no role-dependence. Are the reference stimuli again of mid-level magnitude?

References

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Stevens, J. C., & Marks, L. E. (1965). Cross-modality matching of brightness and loudness.. *Proceedings of the National Academy of Sciences of the United States of America, 54*(2), 407. https://doi.org/10.1073/pnas.54.2.407

MathPsych/ICCM/EMPG 2023 ⋆ July 18-21 ⋆ Amsterdam, the Netherlands