

Cross-Modal Matching Experiment and Internal References

Katharina Naumann

Research Methods and Mathematical Psychology, Department of Psychology, University of Tuebingen

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 (Heller, 2021), but also between modalities: the brightness of light and the loudness of sound.

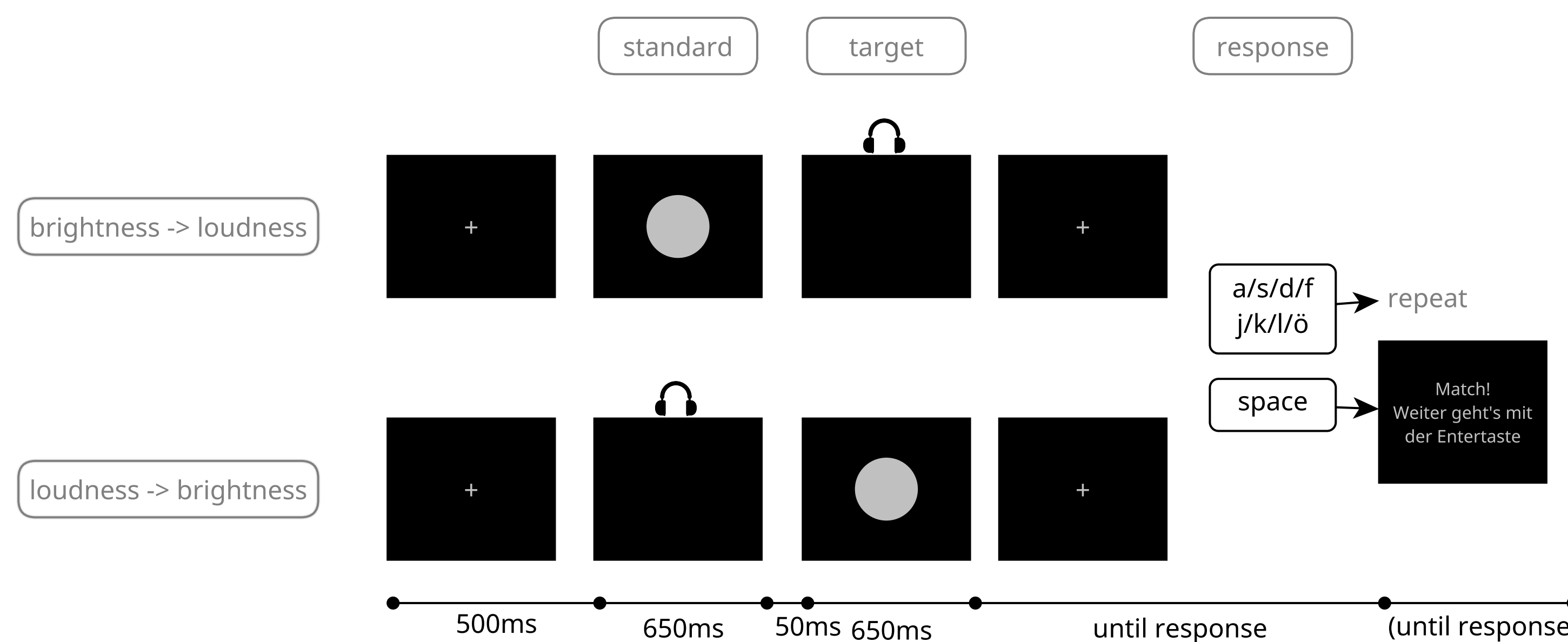


Figure 1: Single trial of matching experiment.

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.

Cross-dimensional Representation of Matching Task

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

$$W(1) = \frac{\psi_l(x_1^{b,l}) - \psi_l(\rho_+^{l \leftarrow b})}{\psi_b(x^b) - \psi_b(\rho_+^{b \rightarrow l})}$$

W cognitive weighting function; $W(1)$ is not necessarily 1.

1 adjustment ratio, 'adjust light so that it appears equally intense as sound'

x^l stimulus level of standard, e. g. sound pressure level of auditory stimulus

$x_1^{l,b}$ adjusted stimulus level, e. g. luminance of visual stimulus
 $\rho^{l \rightarrow b}$ reference level on standard dimension
 $\rho^{b \leftarrow l}$ reference level on variable dimension
 ψ_l and ψ_b psychophysical functions; here power laws $\psi_l(x) = \alpha_l x^{\beta_l}$ and $\psi_b(x) = \alpha_b x^{\beta_b}$

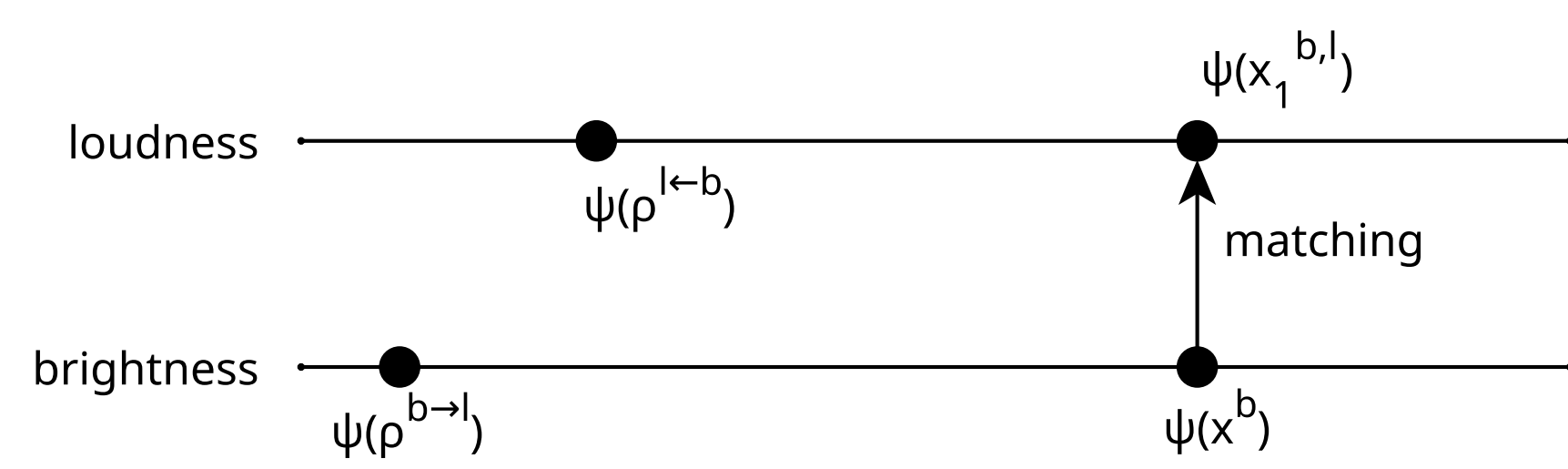


Figure 2: Illustration of cross-dimensional matching.

Are the Reference Stimuli role-independent?

Theoretical predictions for cross-dimensional matching curves assuming

1) role-independent reference stimuli, i. e. $\rho_+^{b \leftarrow l} = \rho_+^{b \rightarrow l}$ and $\rho_+^{l \leftarrow b} = \rho_+^{l \rightarrow b}$

2) role-dependent reference stimuli, i. e. $\rho_+^{b \leftarrow l} \neq \rho_+^{b \rightarrow l}$ and $\rho_+^{l \leftarrow b} \neq \rho_+^{l \rightarrow b}$

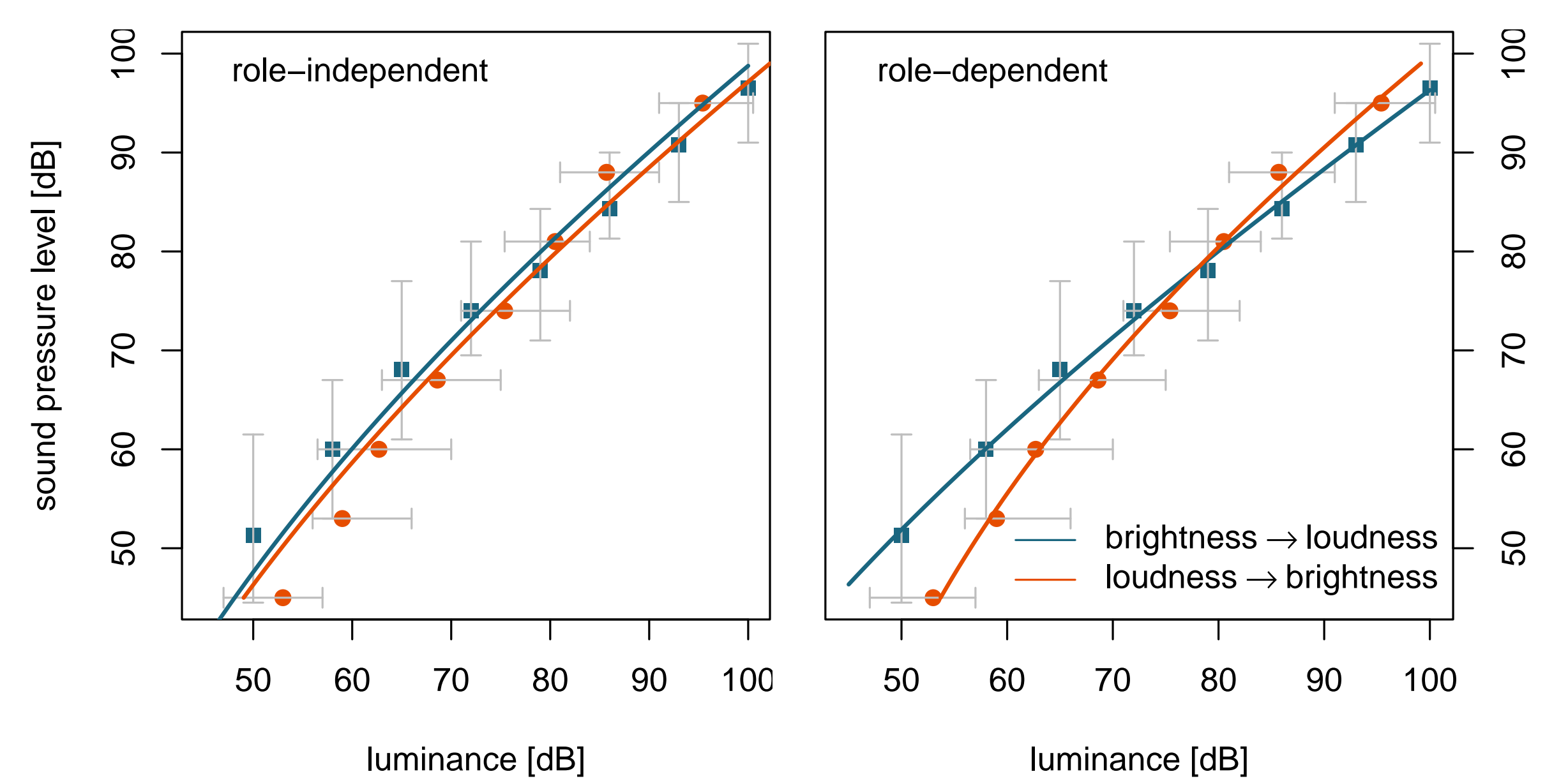


Figure 3: Matching data (circles and rectangles) of ten subjects from Stevens and Marks (1965), showing the often-replicated and so-called regression effect, that is, the stimulus range of the manipulated modality is shortened. Bars are inter-quartile ranges. Lines show Heller's (2021) theoretical predictions for cross-dimensional matching curves assuming role-independence (left), and role-dependence (right). Cross-dimensional matching curves are $m_{b,l}(x^b) = x_1^{b,l} = \psi_l^{-1}[W(1) \cdot [\psi_b(x^b) - \psi_b(\rho_+^{b \rightarrow l})] + \psi_l(\rho_+^{l \leftarrow b})]$ and $m_{l,b}(y^l) = y_1^{l,b} = \psi_b^{-1}[W(1) \cdot [\psi_l(y^l) - \psi_l(\rho_+^{l \rightarrow b})] + \psi_b(\rho_+^{b \leftarrow l})]$.

Results from Matching Experiment

• loudness → brightness • brightness → loudness

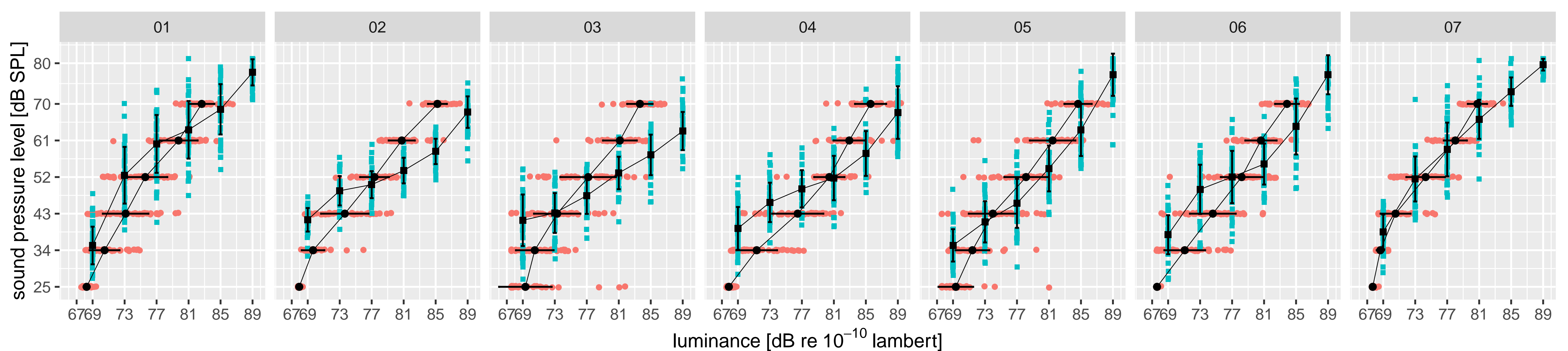


Figure 4: Magnitude productions of seven subjects. For each of the six standards on both modalities, every subject produced 48 matches within 12 experimental blocks. Means and standard deviations are displayed in black, with lines connecting the means.

Conclusions & Work in Progress

- Magnitude productions on individual level show a shortening of the range of the adjusted stimulus intensity in most cases. This replicates the results of Stevens and Marks (1965).
- Individual variability of matches is high.
- To compare the models with and without reference stimulus equality restriction conduct Maximum Likelihood parameter estimation.
- Power calculation for replication experiment; What is the minimal relevant deviation of pairwise equality of reference stimuli?
- Build Bayesian hierarchical model to draw conclusions on interindividual level.

References

- Heller, J. (2021). Internal references in cross-modal judgments: A global psychophysical perspective [Publisher: American Psychological Association]. *Psychological Review*, 128(3), 509–524. <https://doi.org/10.1037/rev0000280>
- Luce, R. D., Steingrimsón, R., & Narens, L. (2010). Are psychophysical scales of intensities the same or different when stimuli vary on other dimensions? theory with experiments varying loudness and pitch. [Number: 4]. *Psychological Review*, 117(4), 1247–1258. <https://doi.org/10.1037/a0020174>
- Stevens, J. C., & Marks, L. E. (1965). Cross-modality matching of brightness and loudness. [Number: 2]. *Proceedings of the National Academy of Sciences of the United States of America*, 54(2), 407.