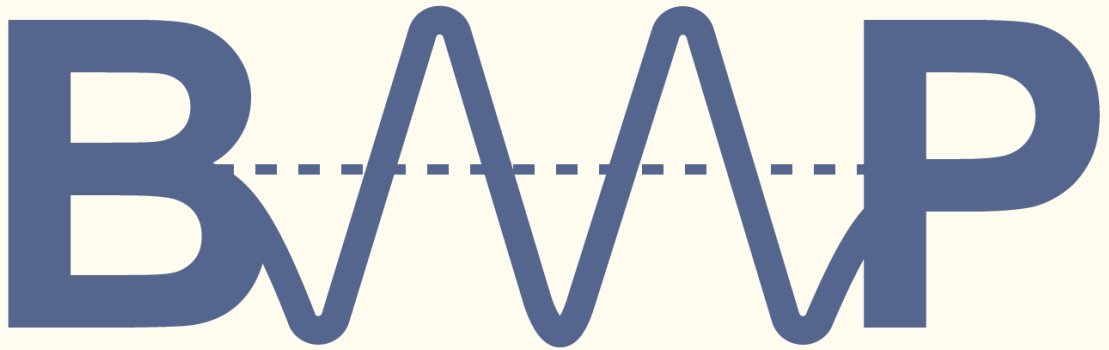
An incremental cue-based approach to extended lexical tone training

Yanyu Li, Laurence White & Ghada Khattab

Newcastle University



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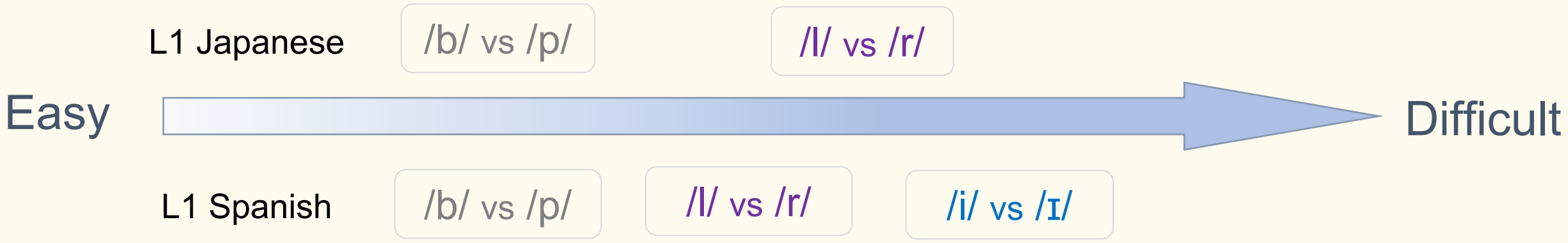
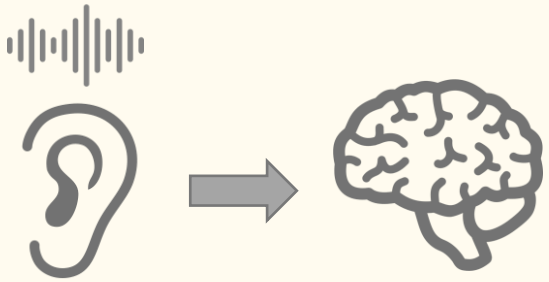
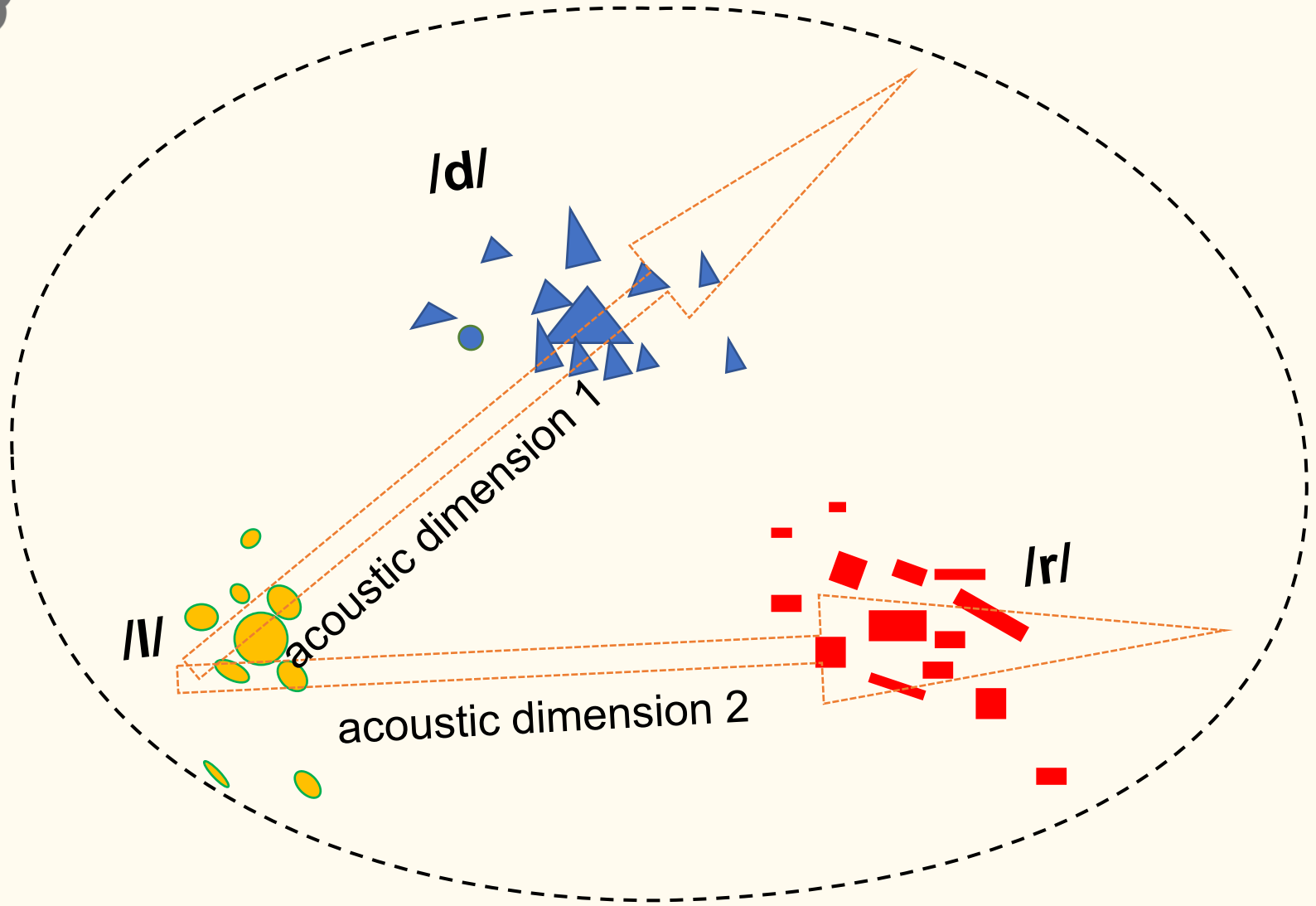
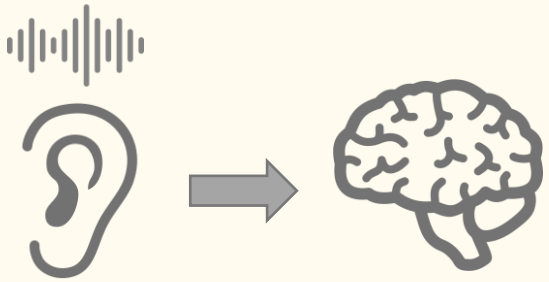
Some contrasts are more difficult than others
Language-specific perceptual biases



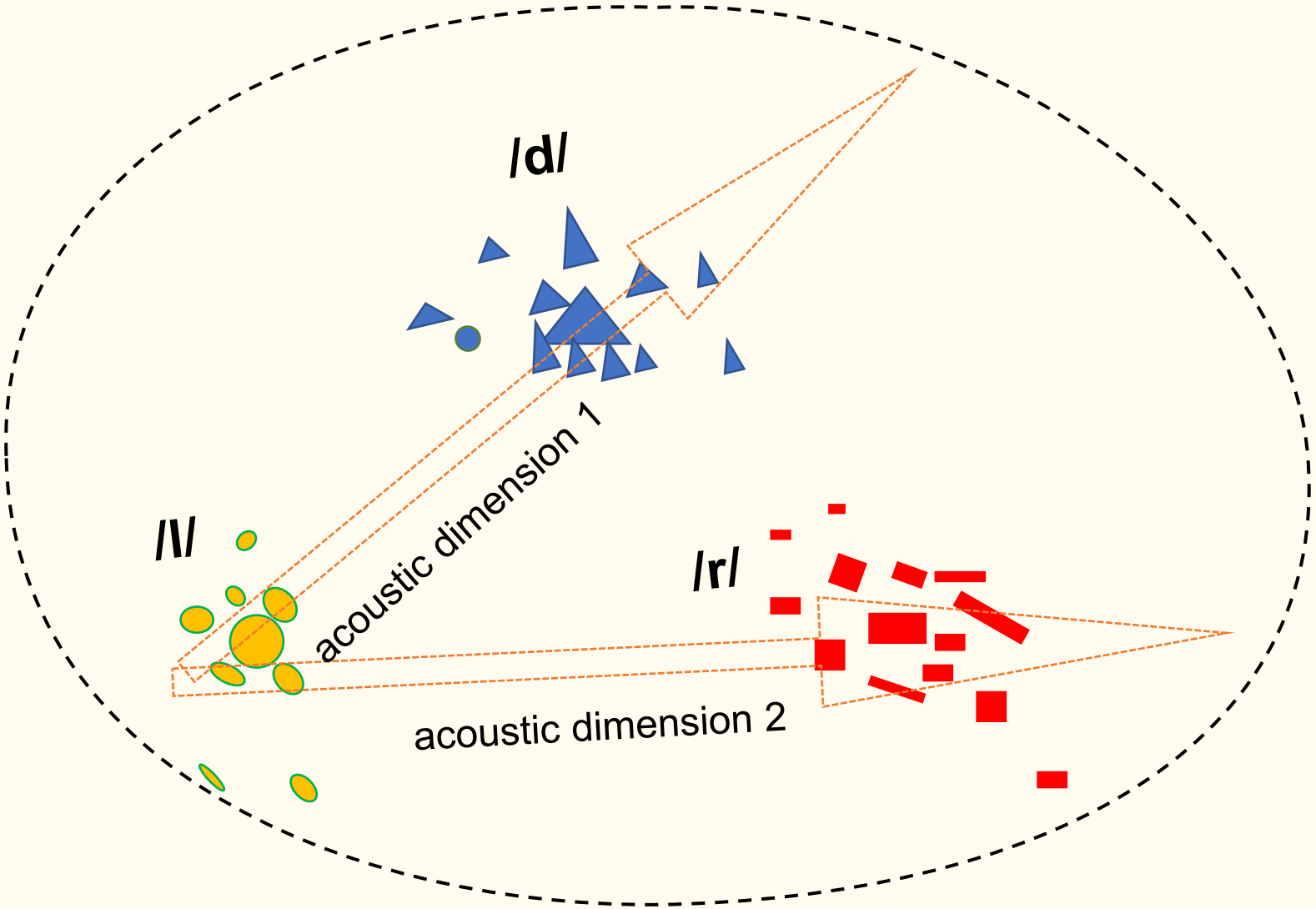



/d/
/l/
/r/
acoustic dimension 1
acoustic dimension 2



Theories such as

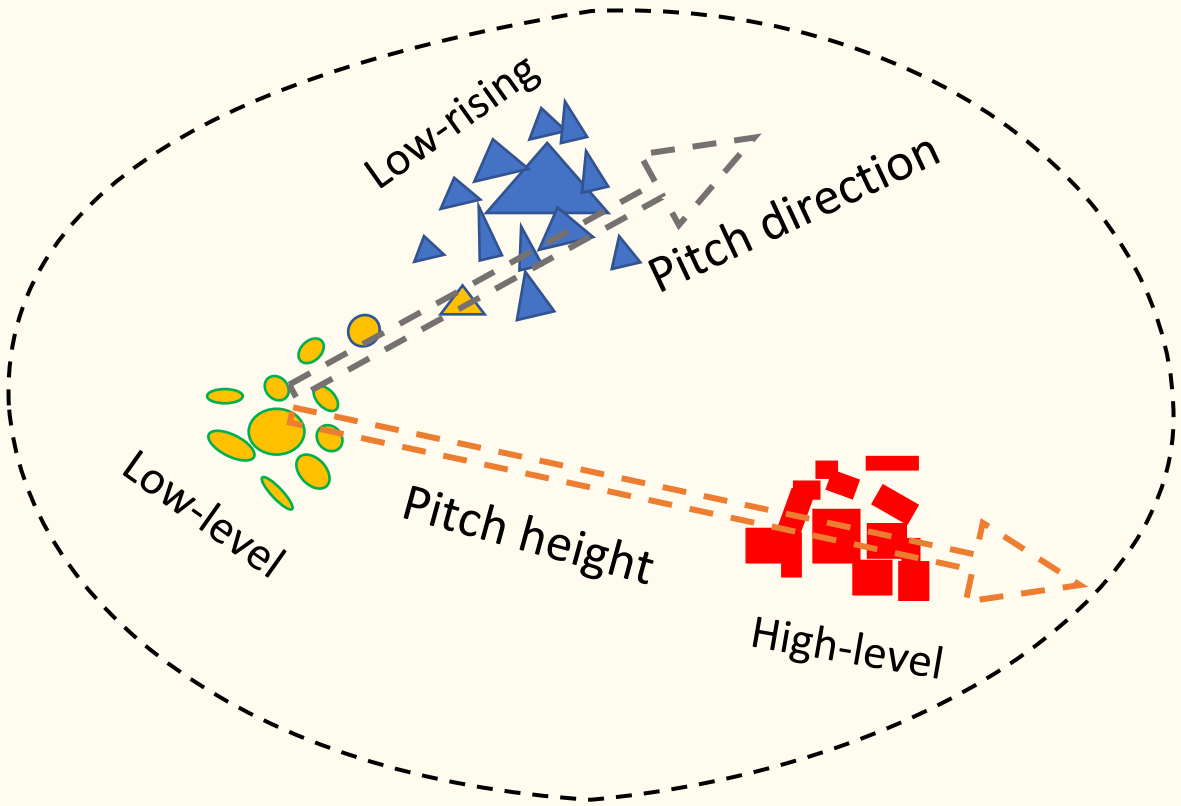
- Perceptual magnet effect (Kuhl and Iverson, 1995)
- Attention-to-dimension (A2D) models (Francis & Nusbaum, 2002)
- Automatic Selective Perception (ASP) (Strange, 2011)



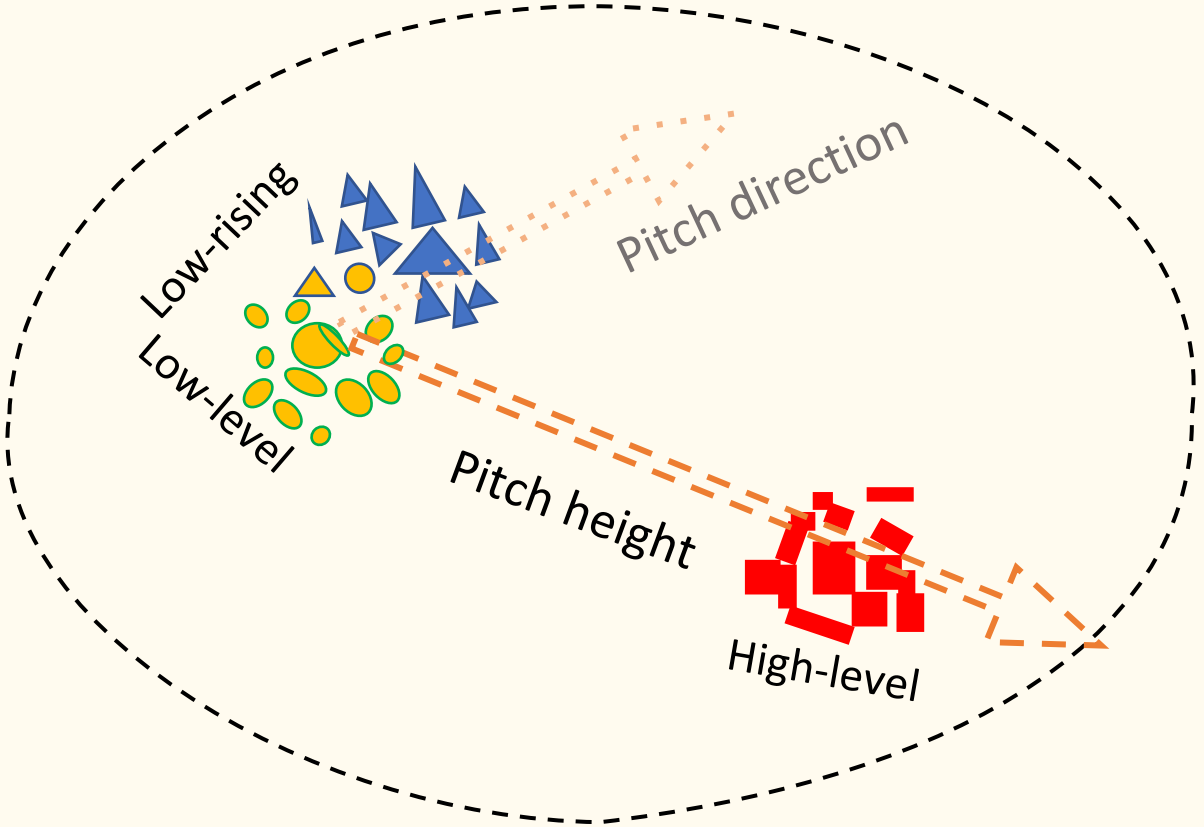
Lexical tone

e.g., tú vs tù

(Chandrasekaran et al., 2010; Gandour, 1983)



Tonal listeners



Non-tonal listeners

Cue exaggeration to redirect attention? – Incremental cue training

Cue exaggeration on “pitch direction”, i.e., tonal slope

L1 English listeners with no tonal language experience

Training 1 (**Most** exaggerated) → Training 2 (**Less** exaggerated) → Training 3 (**Least** exaggerated)

- /i/-/ɪ/ (Kondaurova & Francis, 2010)
- /l/-/r/ (Iverson et al., 2005)

Testing the effect of the extended incremental cue training

N = 15

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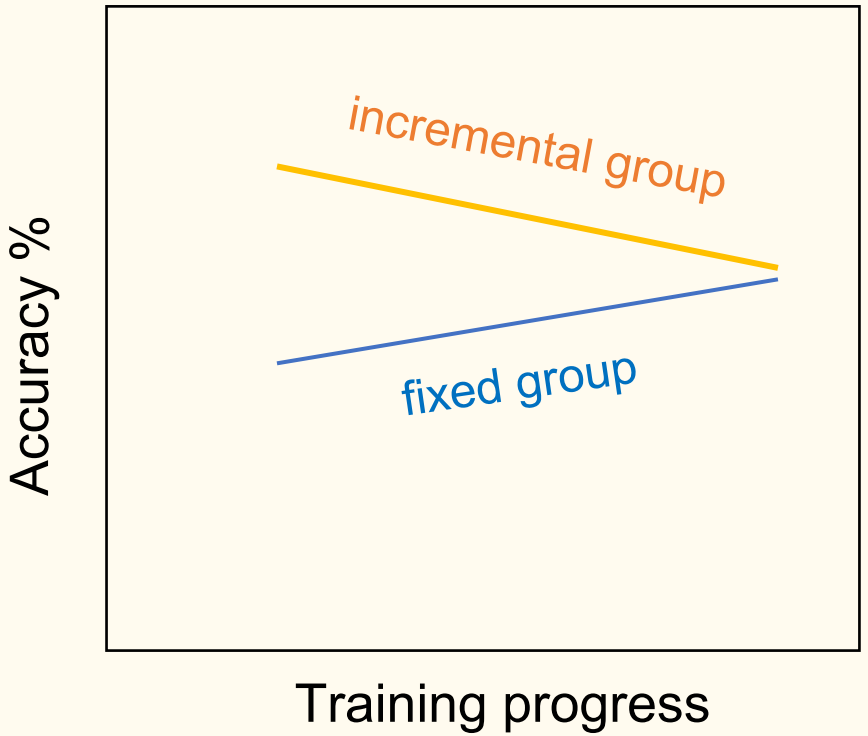
- Is incremental cue training more beneficial than fixed unexaggerated stimuli exposure in lexical tone perceptual learning?
- How does the effect change for a training course lasting **multiple days**?



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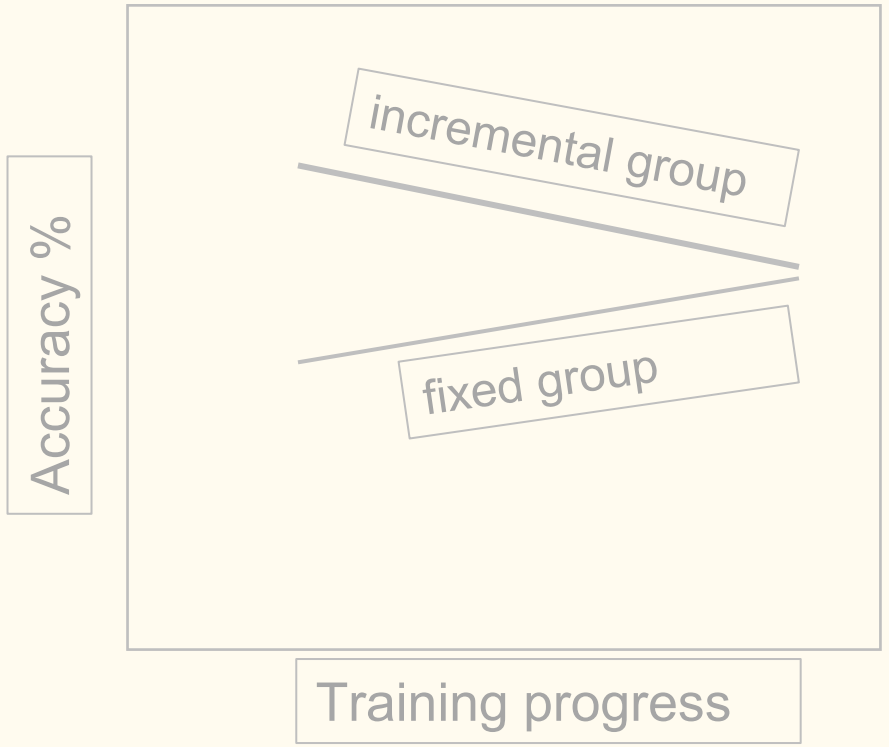
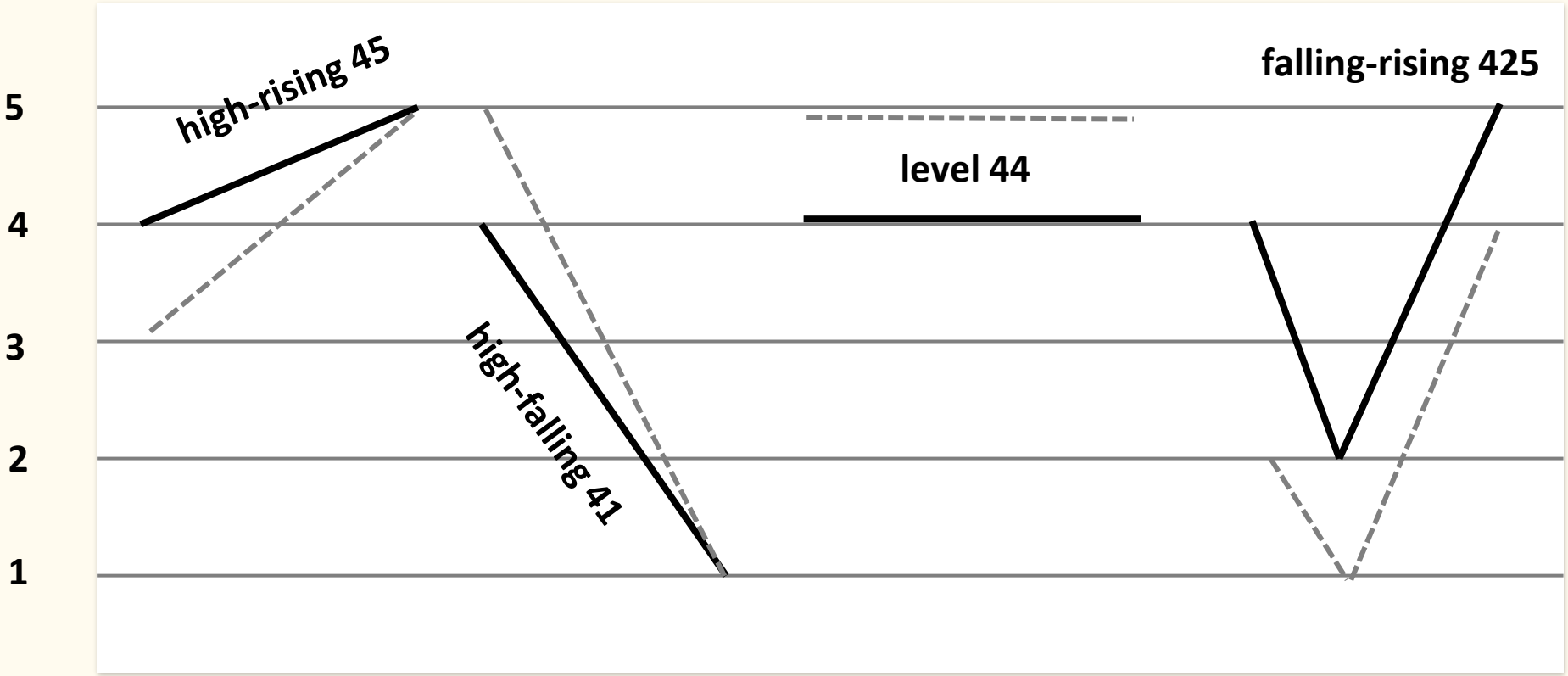
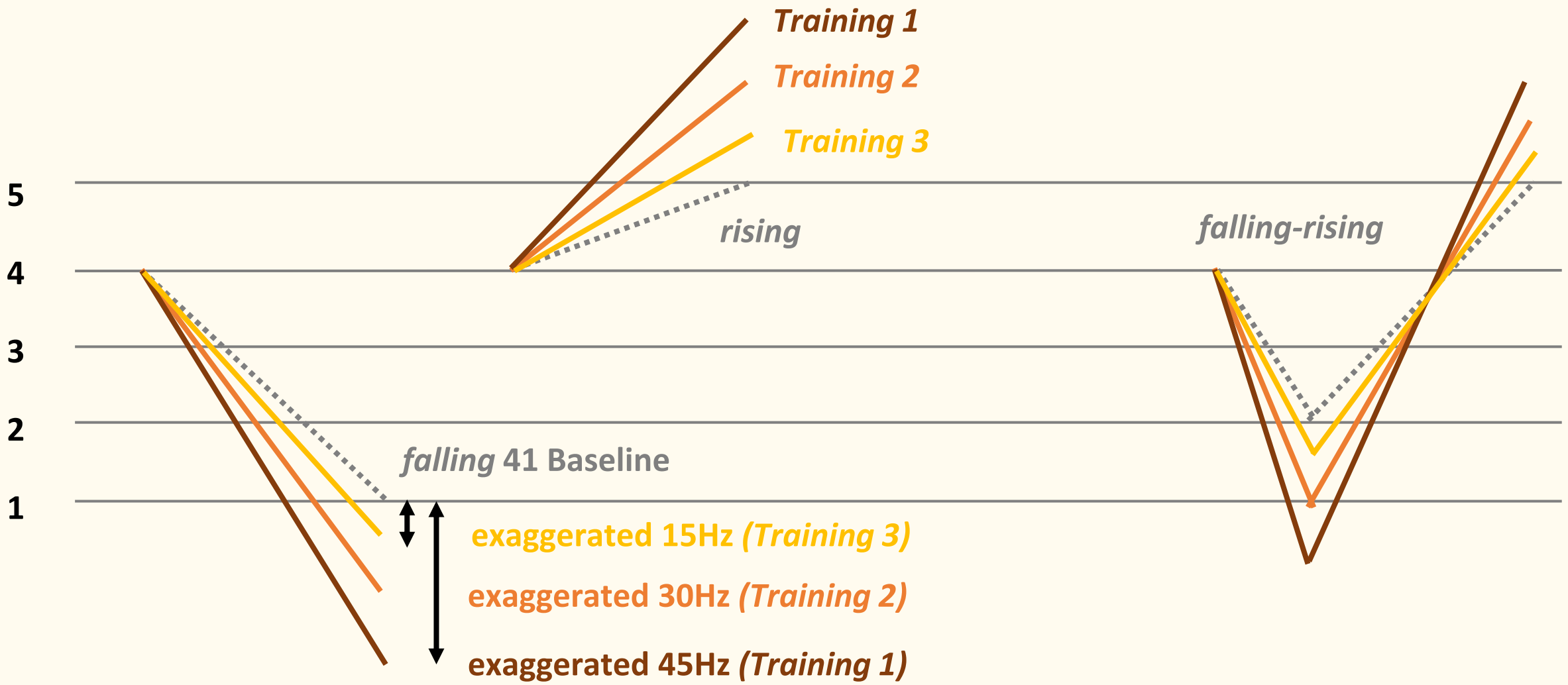


36 baseline tonal stimuli (baseline)

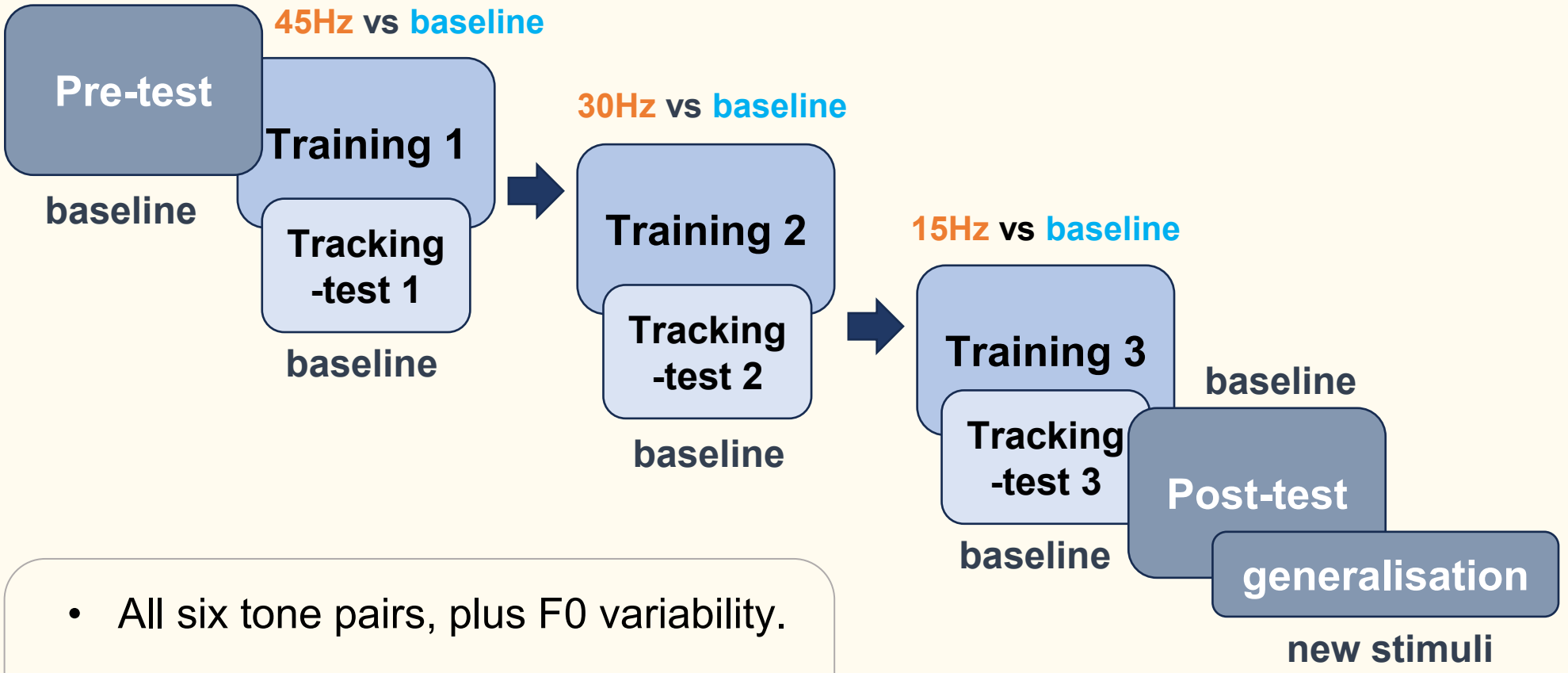


9 Syllables: /pa:/, /ta:/, /ka:/, /pi:/, /ti:/, /ki:/, /pu:/, /tu:/, and /ku:/

Cue exaggeration for incremental group: tonal slope



Extended incremental cue training procedure



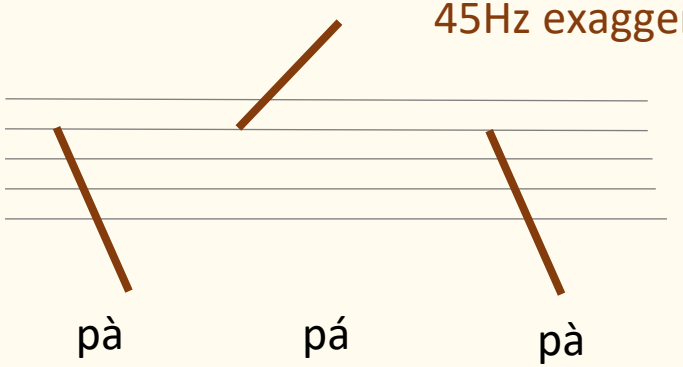
- All six tone pairs, plus F0 variability.
- All sessions used ABX tasks
- Feeback only in Training 1, 2, & 3

ABX trial examples: pà pá pà

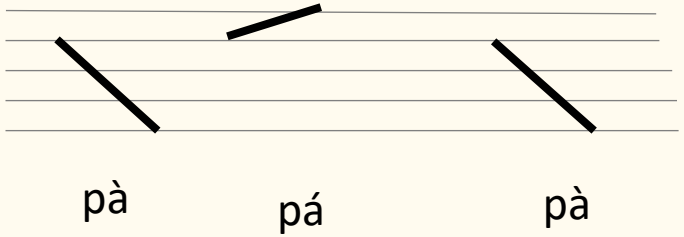
Training 1

Incremental group

45Hz exaggeration

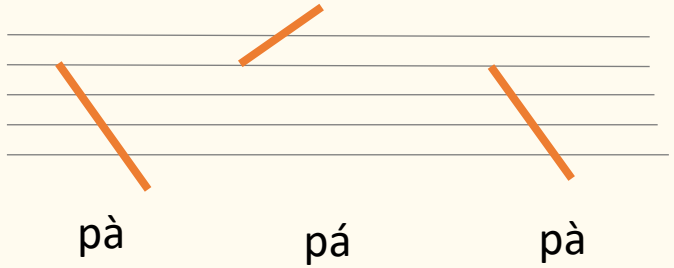


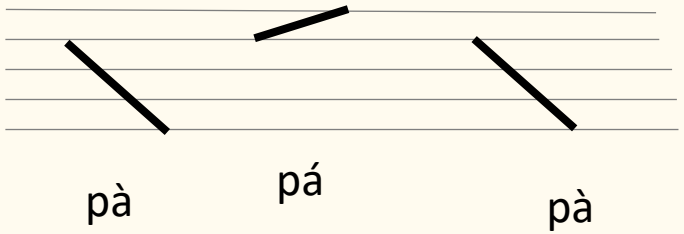
Fixed group



Training 2

30Hz exaggeration





Data analysis: is incremental training more effective?

- Mixed-effect logistic/linear regression models.
- Training or tests data are analysed separately.

training 1, 2, 3

tracking-tests 1, 2, 3

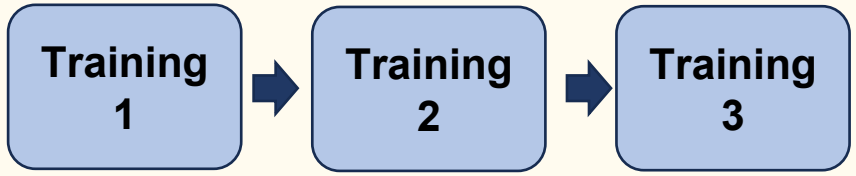
pre- vs post-tests

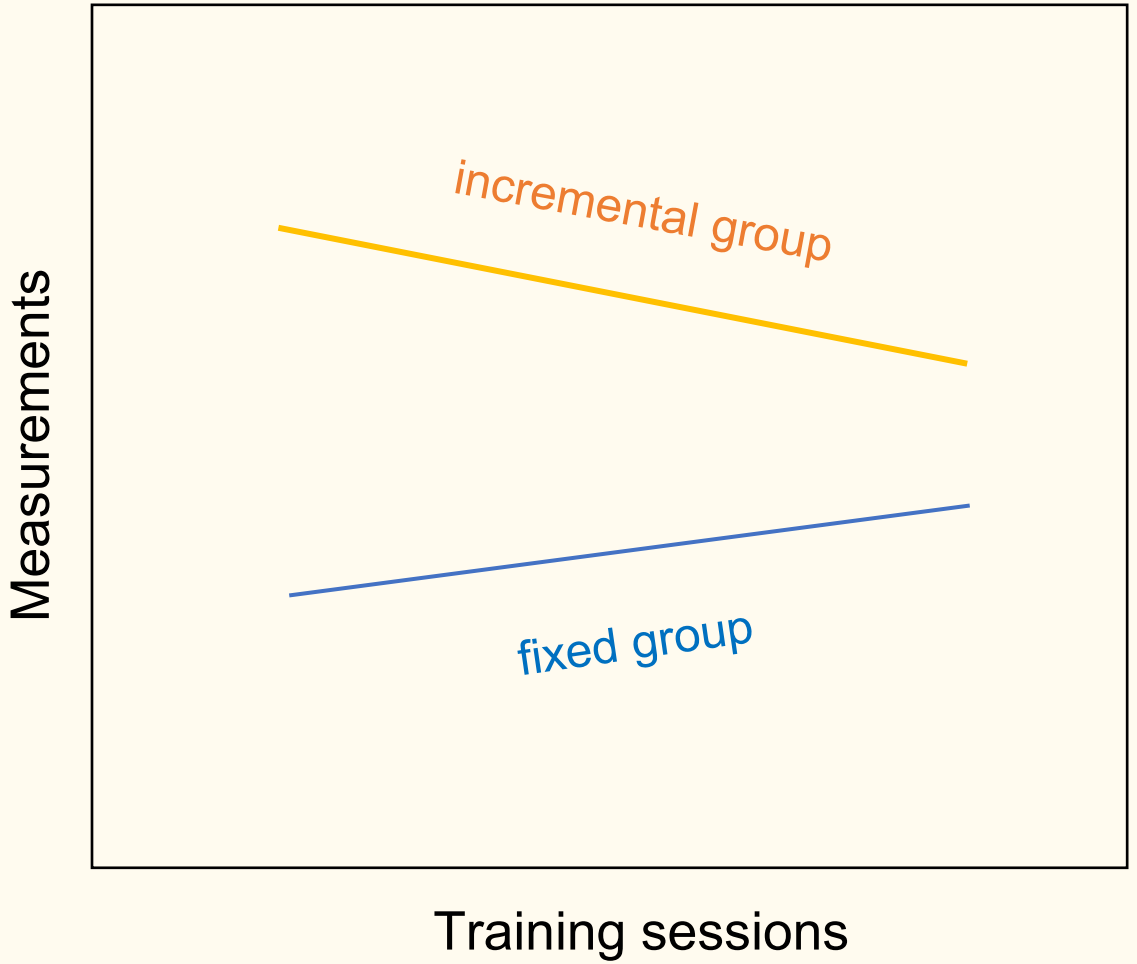
- Model structure:
  - measurement ~ block * training_type + (1+block|participant) + (1|syllable)
  - measurements: RT, accuracy, Balanced Integration Score (BIS), sensitivity (d')

combined accuracy and RT

Predictions in **Training Sessions**

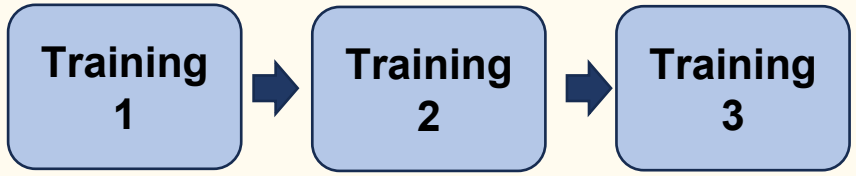
baseline vs **exaggeration**

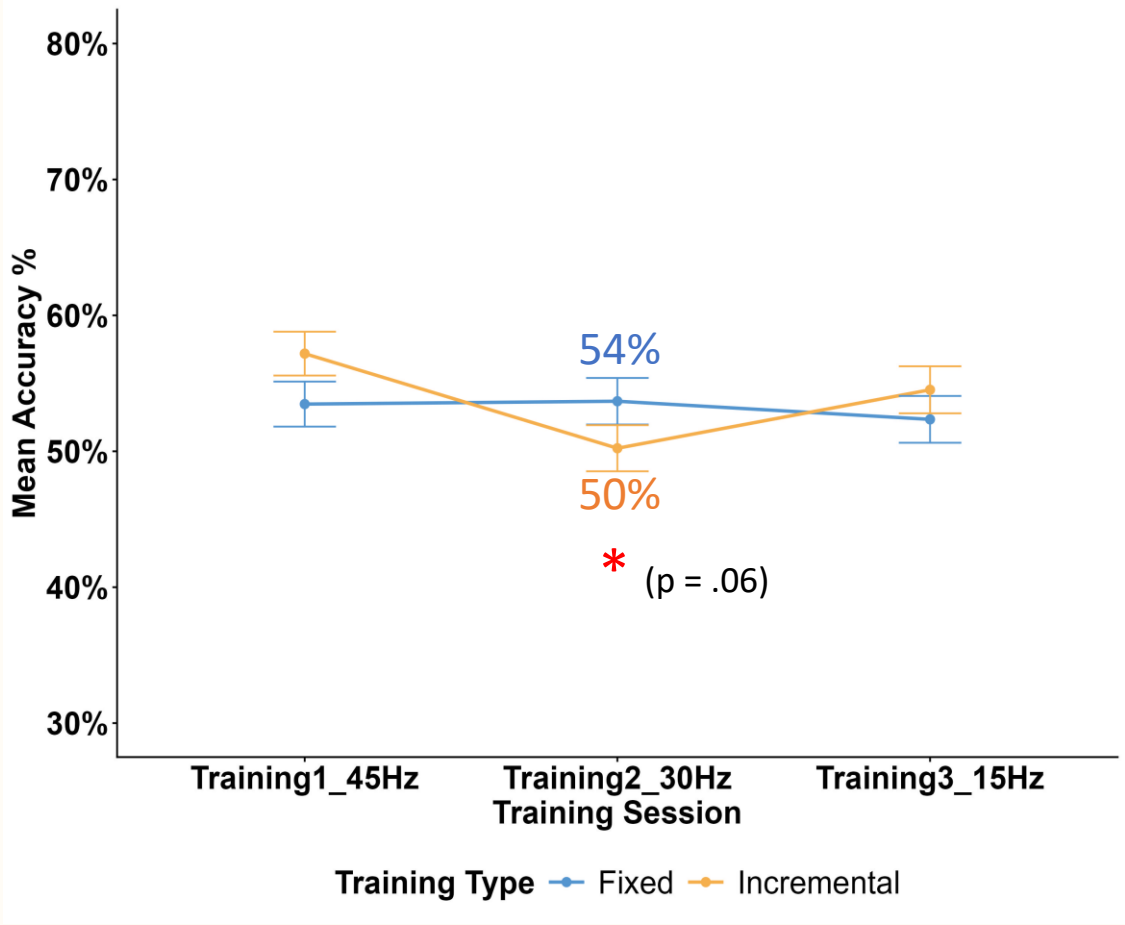




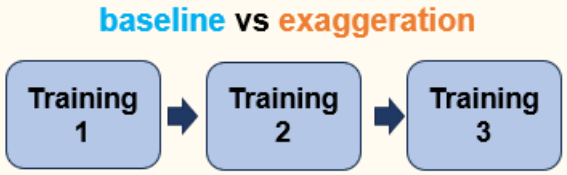
Results: Accuracy

baseline vs **exaggeration**

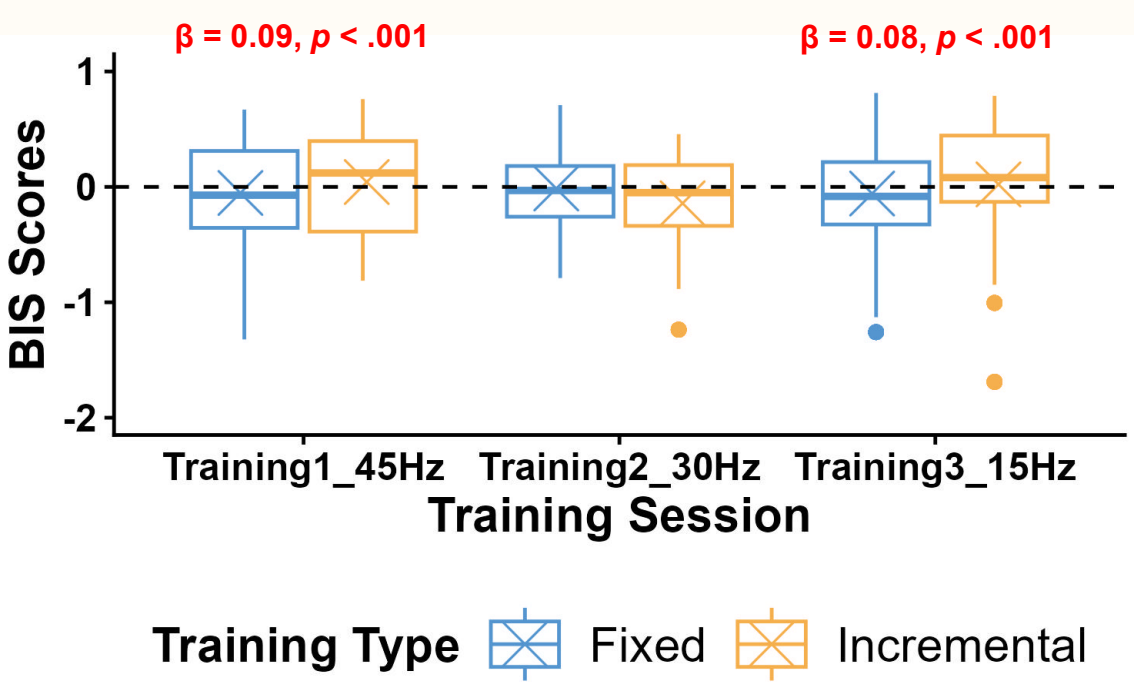




Training: Training Session (p = .07)

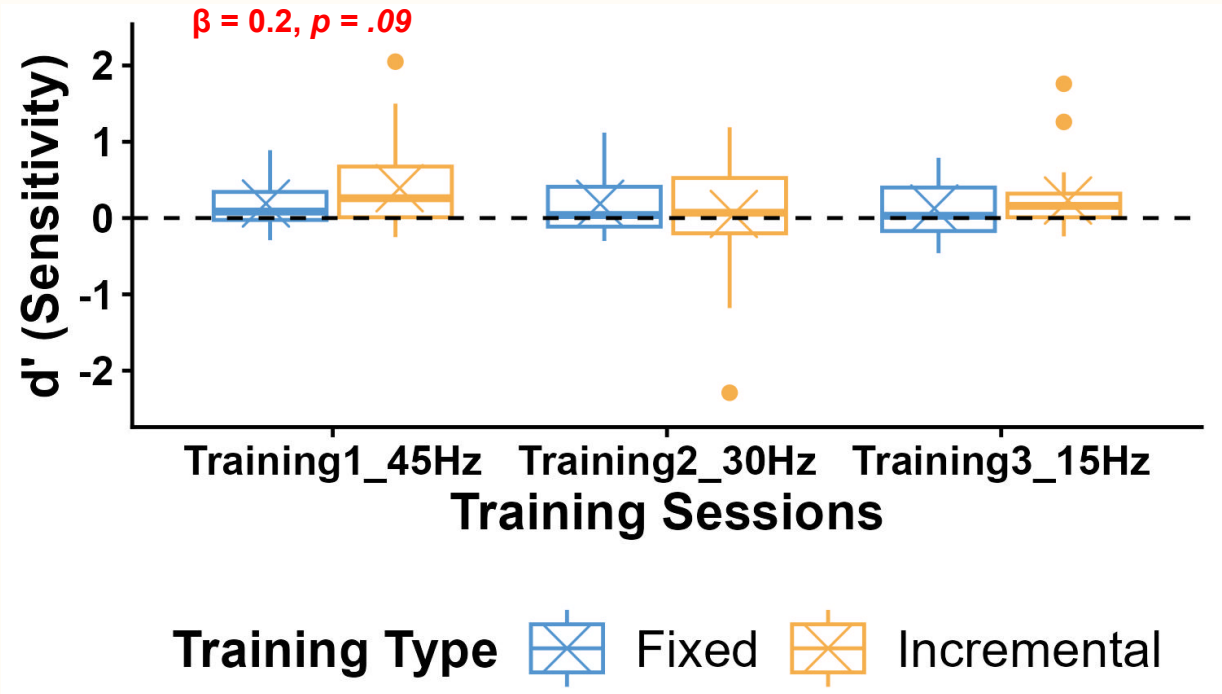


Results: BIS & Sensitivity scores (d')



Training: BIS scores

Training Session * Training Type

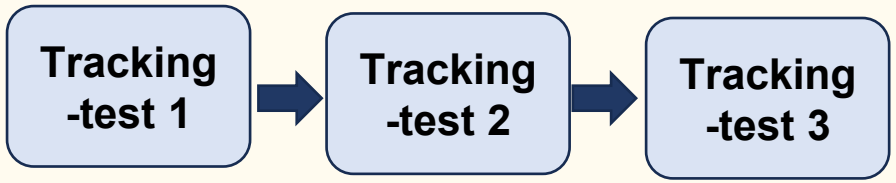


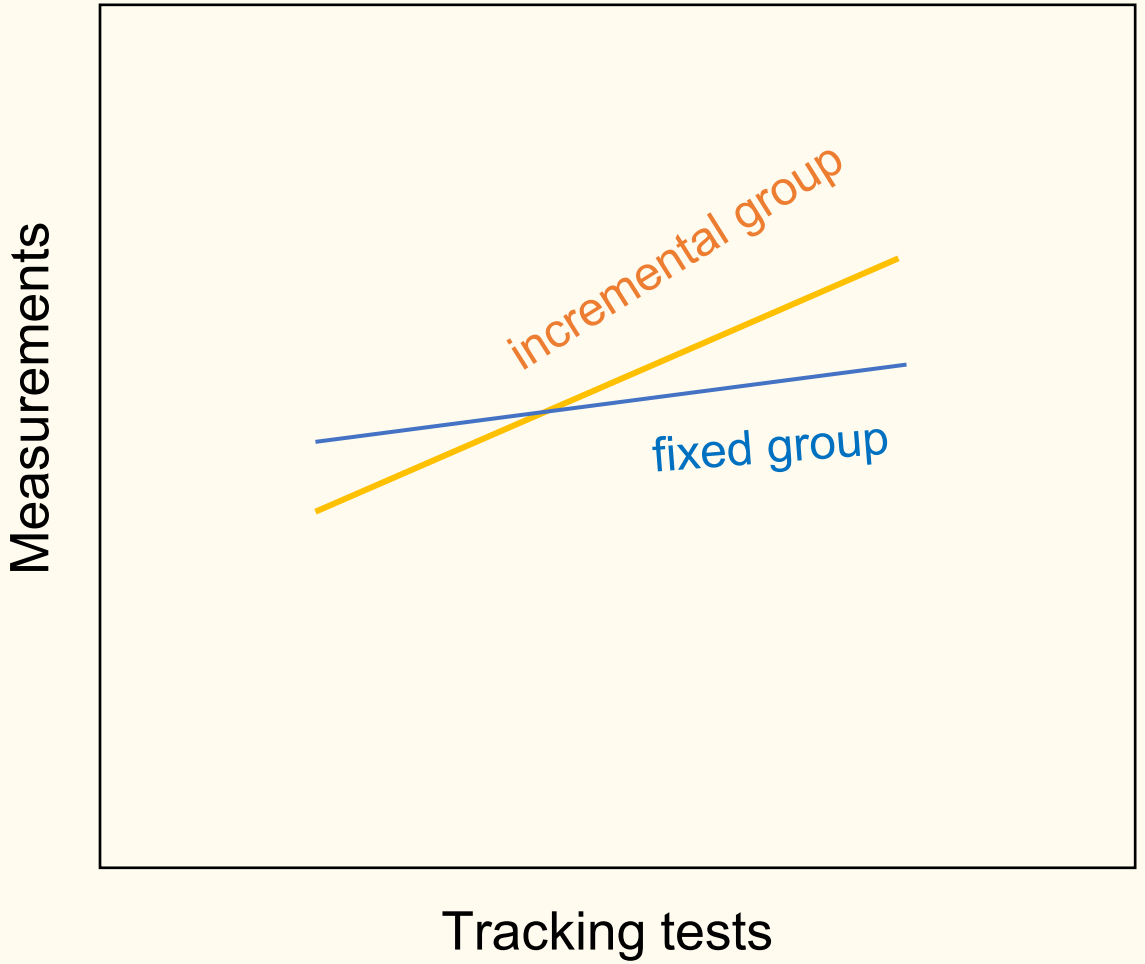
Training: Sensitivity scores (d')

No main/interaction effect

Predictions in **Tracking-tests** immediately following training

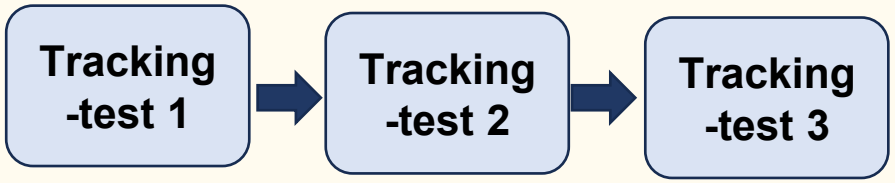
baseline stimuli

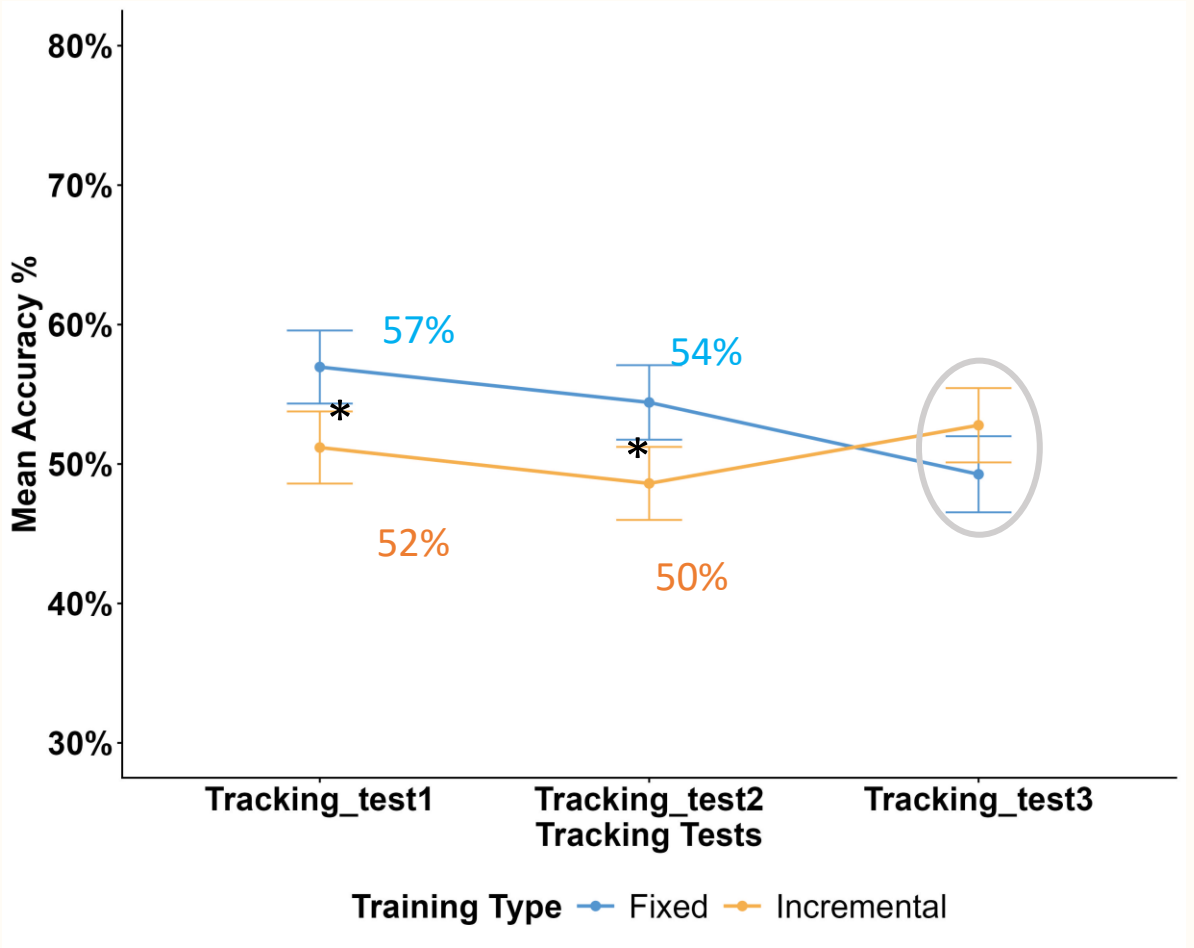




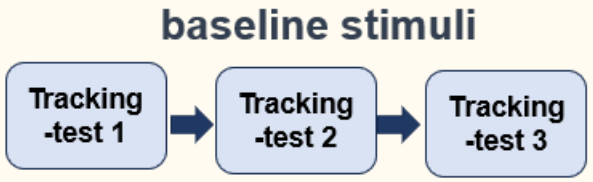
Results: Accuracy

baseline stimuli





Tracking-tests: Training_type * Tracking_test



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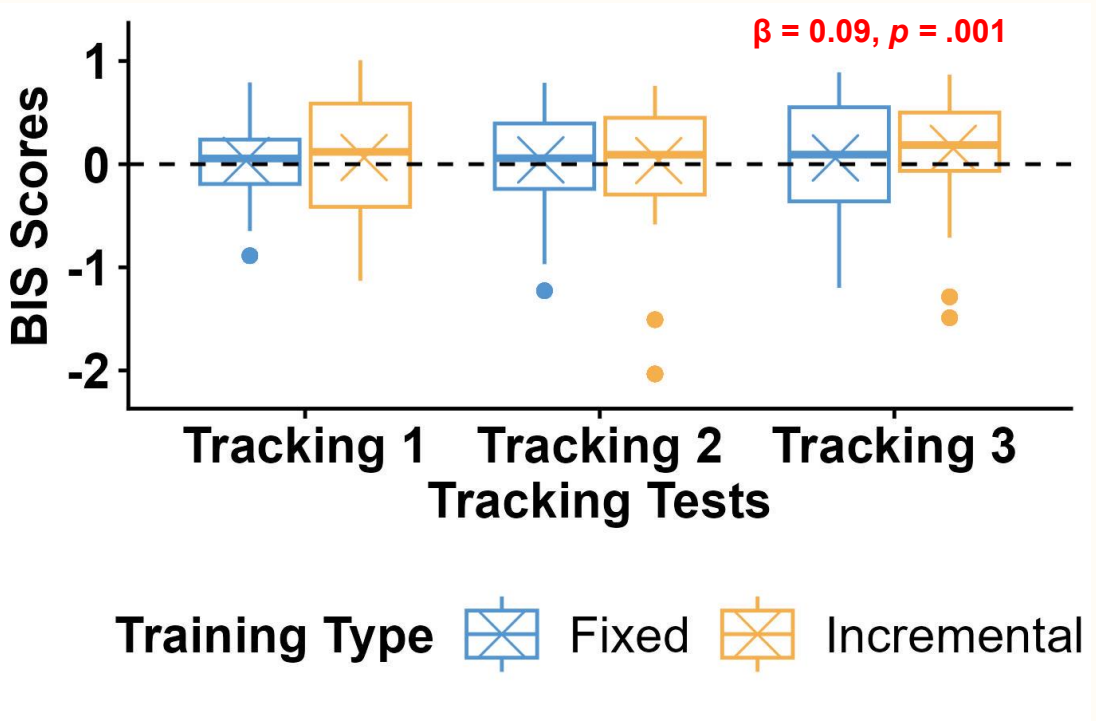
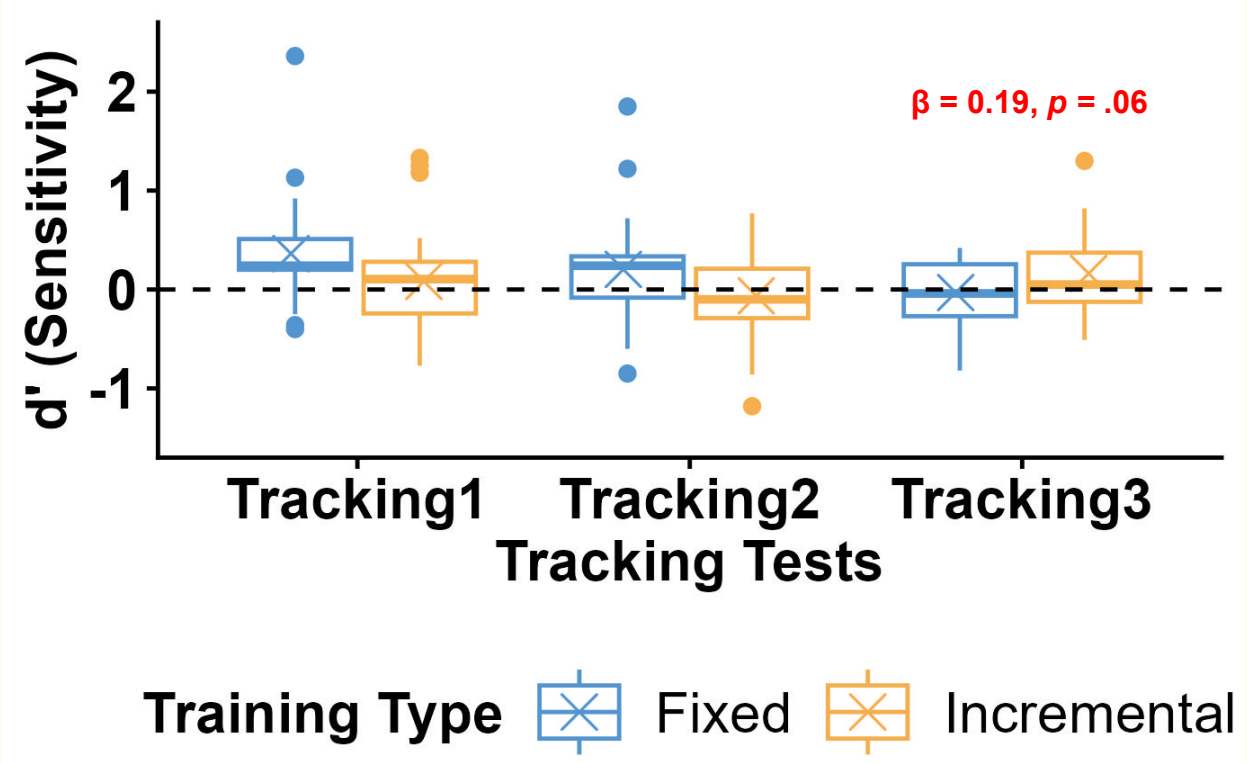


Tracking-test: BIS scores

Training Type : Tracking-test

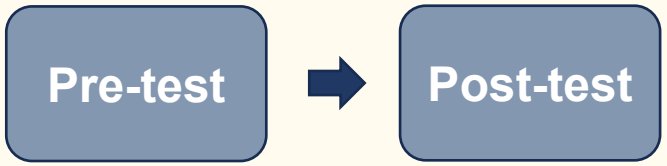


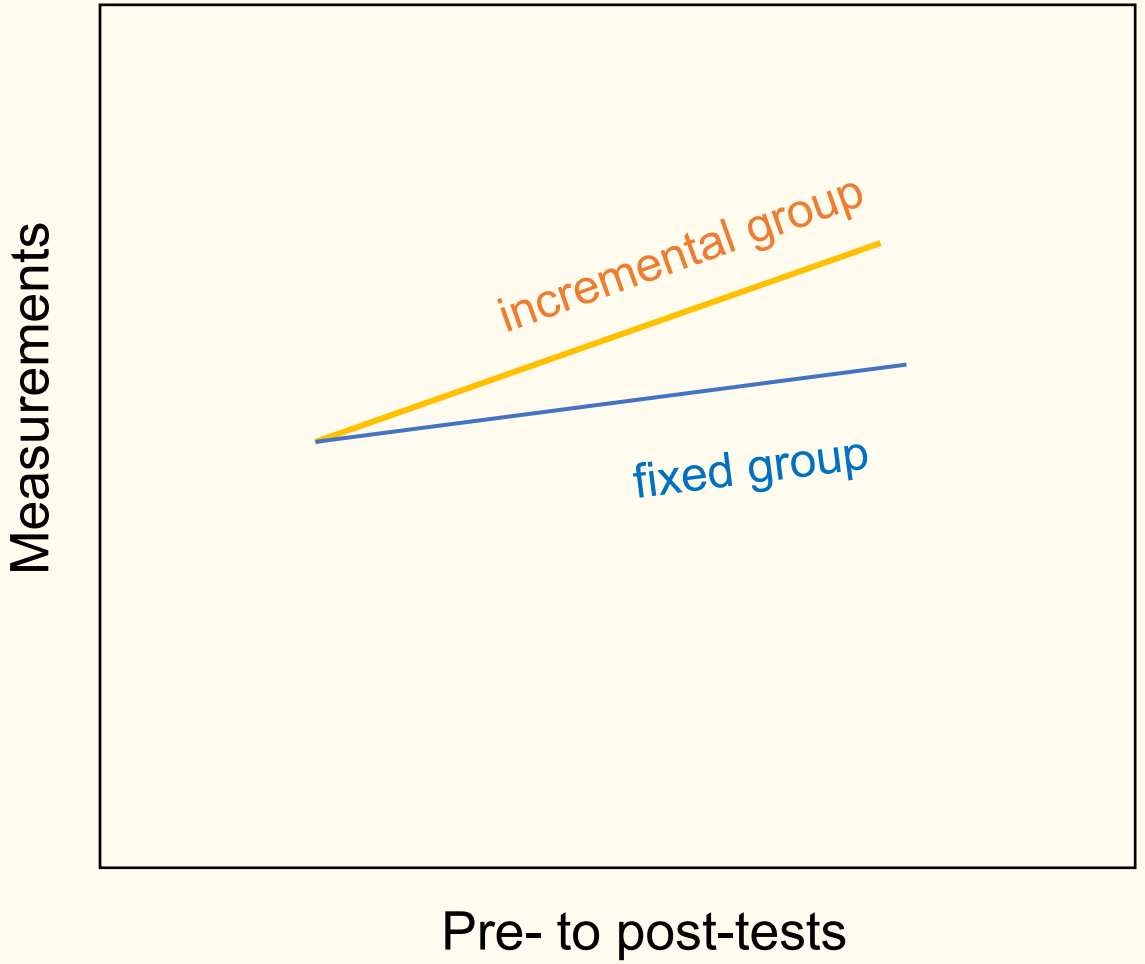
Tracking-test : Sensitivity scores

Training Type * Tracking-test

Predictions from **pre- to post-test**

baseline stimuli

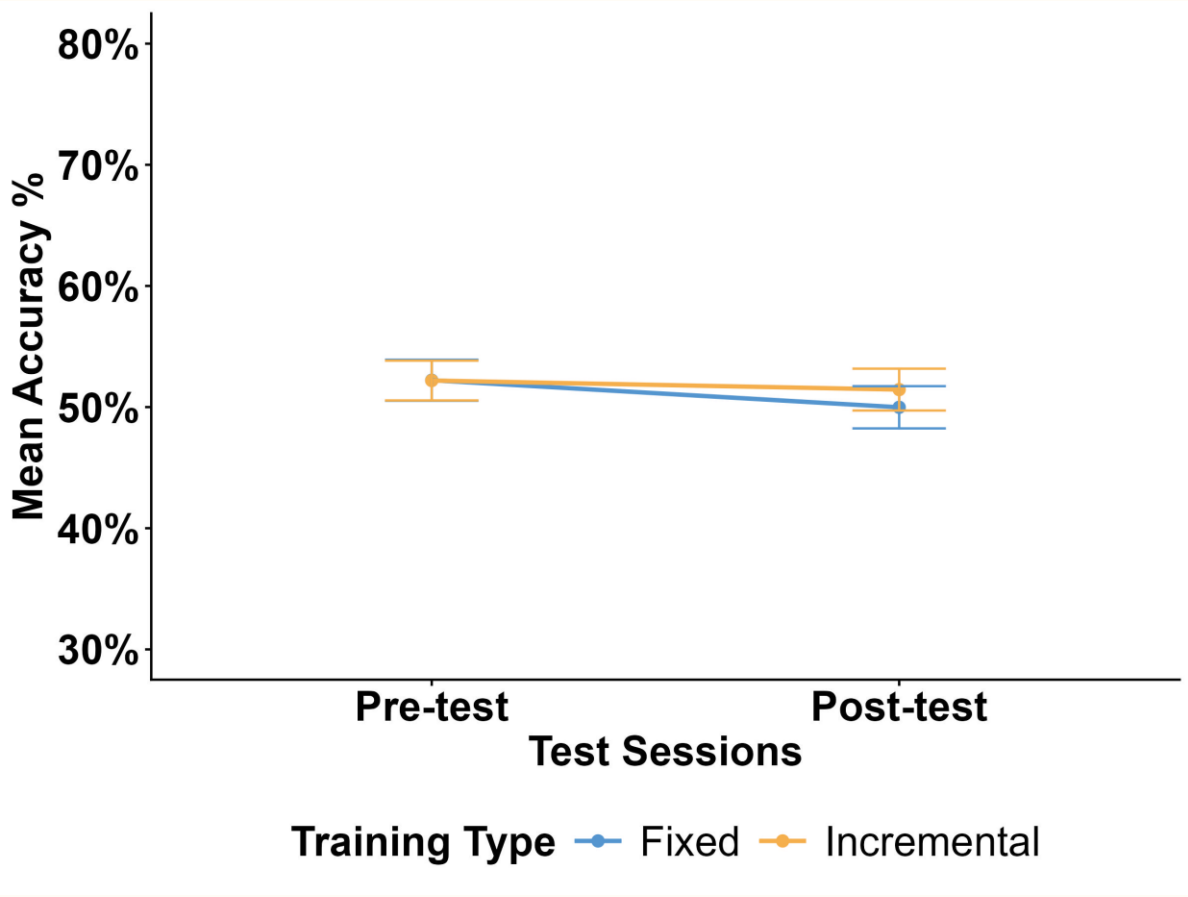




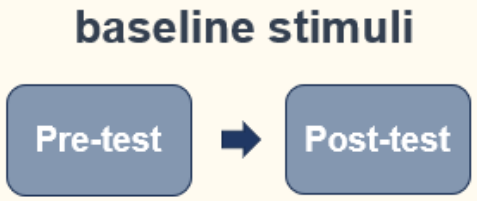
Results: Accuracy

baseline stimuli

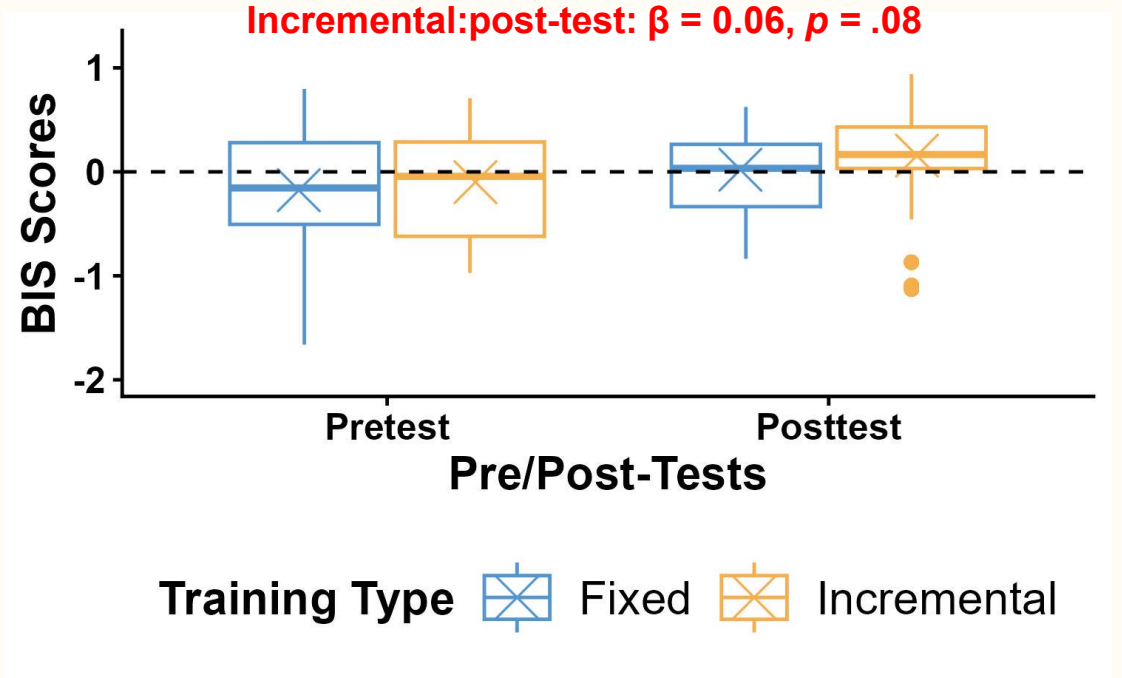
Pre-test → Post-test



Pre-/post-tests: No main/interaction effects

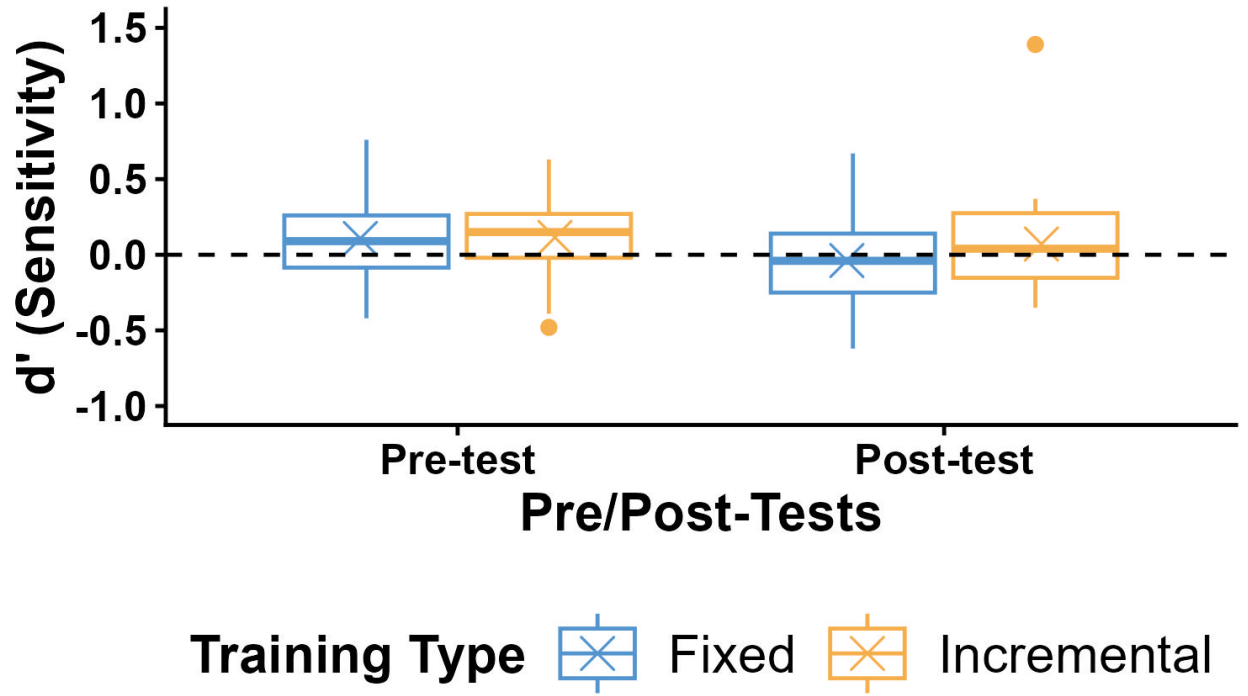


Results: BIS & Sensitivity scores (d')



Pre-/post-test: BIS scores

Training Type x Test Session

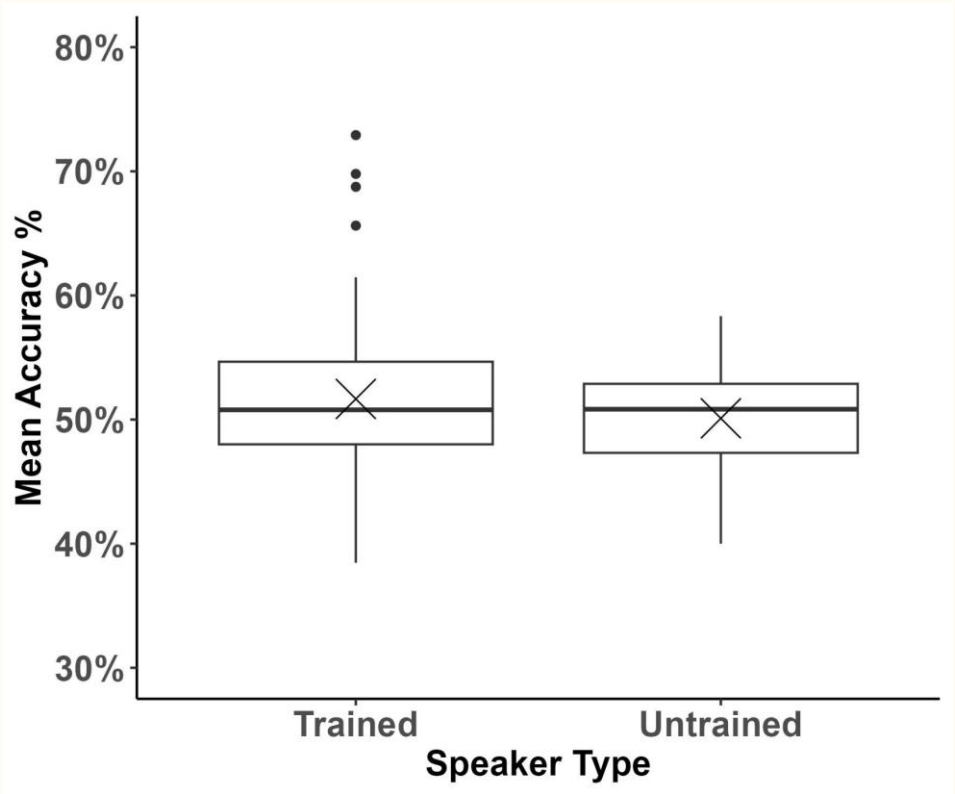


Pre-/post-test: Sensitivity scores

Test Session: *decrease in fixed group, p = .07*

Results in Generalisation test: Accuracy

trained speaker with untrained stimuli
untrained speaker with trained stimuli



Generalisation-test: speaker (p = .06)

Key findings

BIS & Sensitivity (d')

- Perceptual boost in training
- Sustainable benefits in tracking-tests?

Auditory salience

- independent of language experience

Perceptual salience

Statistical regularities

Acoustic-phonetic link

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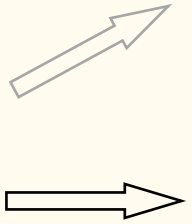


Auditory salience

Perceptual salience

- Dependent of language experience

Key findings

BIS & Sensitivity (d')

- Perceptual boost in training
- Sustainable benefits in tracking-tests?

Auditory / perceptual salience

Statistical regularities

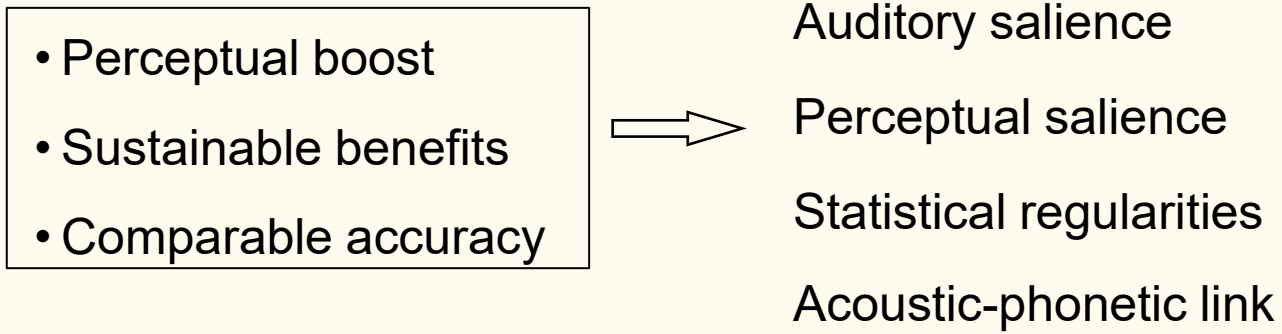
- Categorisation
- Informativeness

Comparable accuracy

Acoustic-phonetic link

- Non-linear but transformative relationship

Open questions…



- What's the mapping mechanism between acoustic cues and phonetic representations if it's not such a straightforward relationship?
  - What are the methodologies to investigate these mechanisms?
- Is the efficacy of cue exaggeration subject to the nature of sound contrasts?
- Bottom-up vs top-down learning?

Dr Laurence White

Prof Ghada Khattab

Newcastle University

国家留学基金管理委员会 CHINA SCHOLARSHIP COUNCIL

Phonetics and Phonology Research Group:
https://blogs.ncl.ac.uk/phonphon/

Thank you

BAAP

Summary page

- Perceptual boost
- Sustainable benefits
- Comparable accuracy

→

Auditory salience

Perceptual salience

Statistical regularities

Acoustic-phonetic link

https://yanyu-li.github.io/

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References

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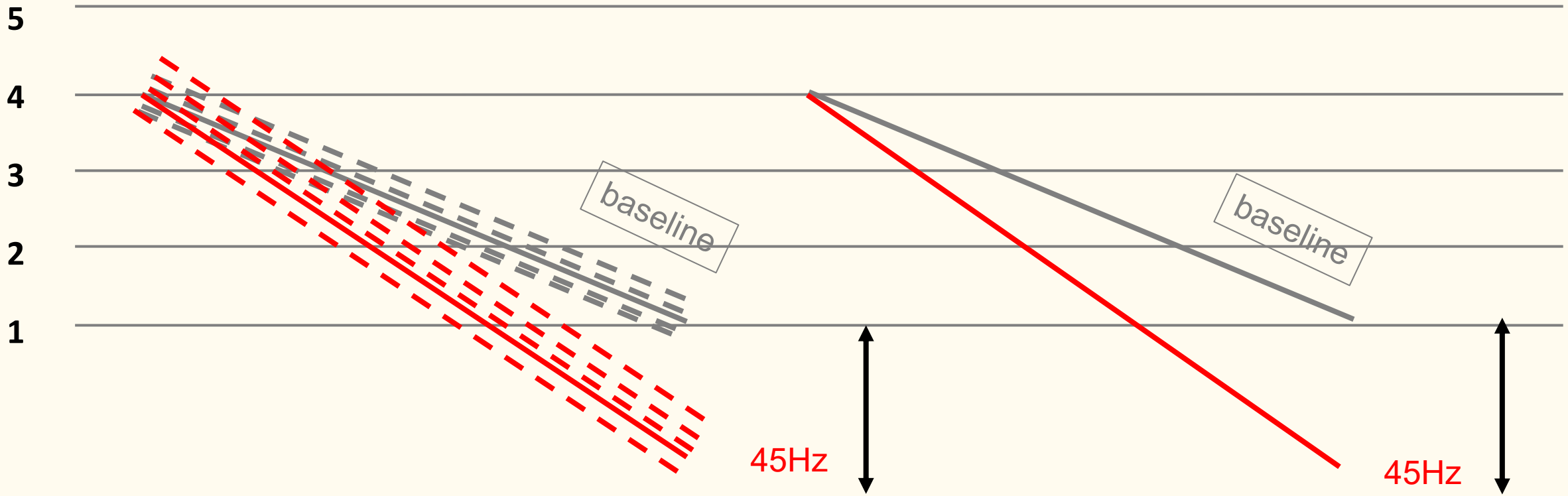
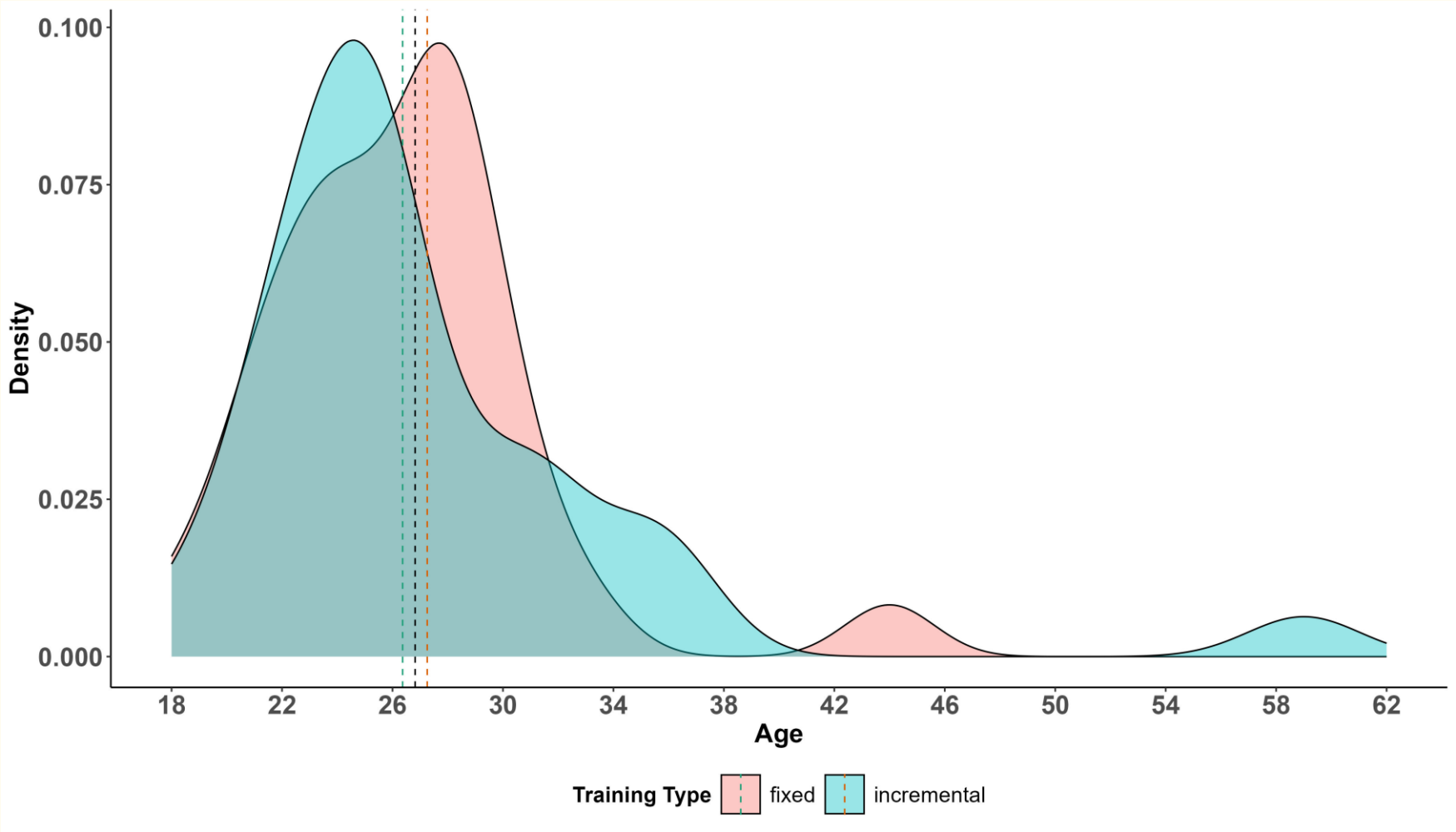
For all tonal stimuli: F0 variation

Varying average F0 height while keeping tonal slope the same.



Demographic information: age



BIS: measurement

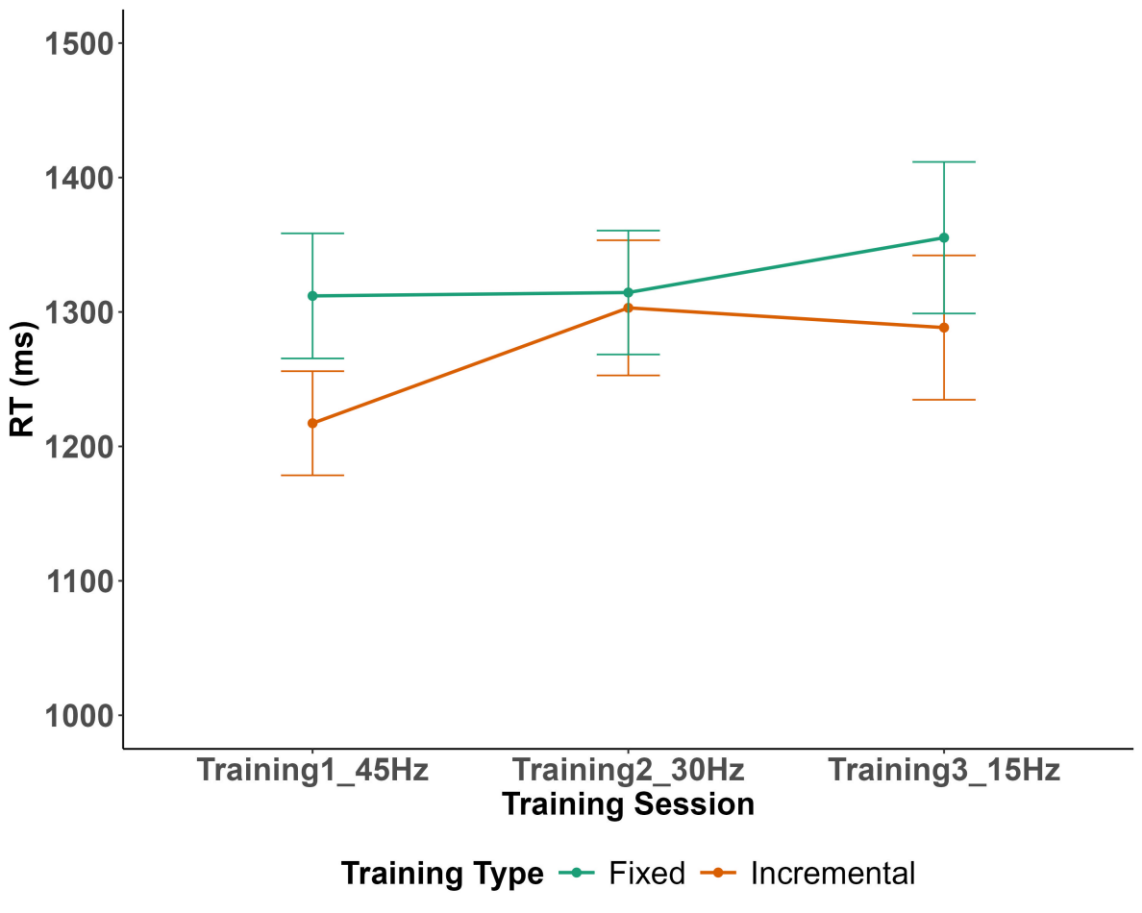
$$BIS_{i,j} = Z_{PC_{i,j}} - Z_{\overline{RT_{i,j}}}$$

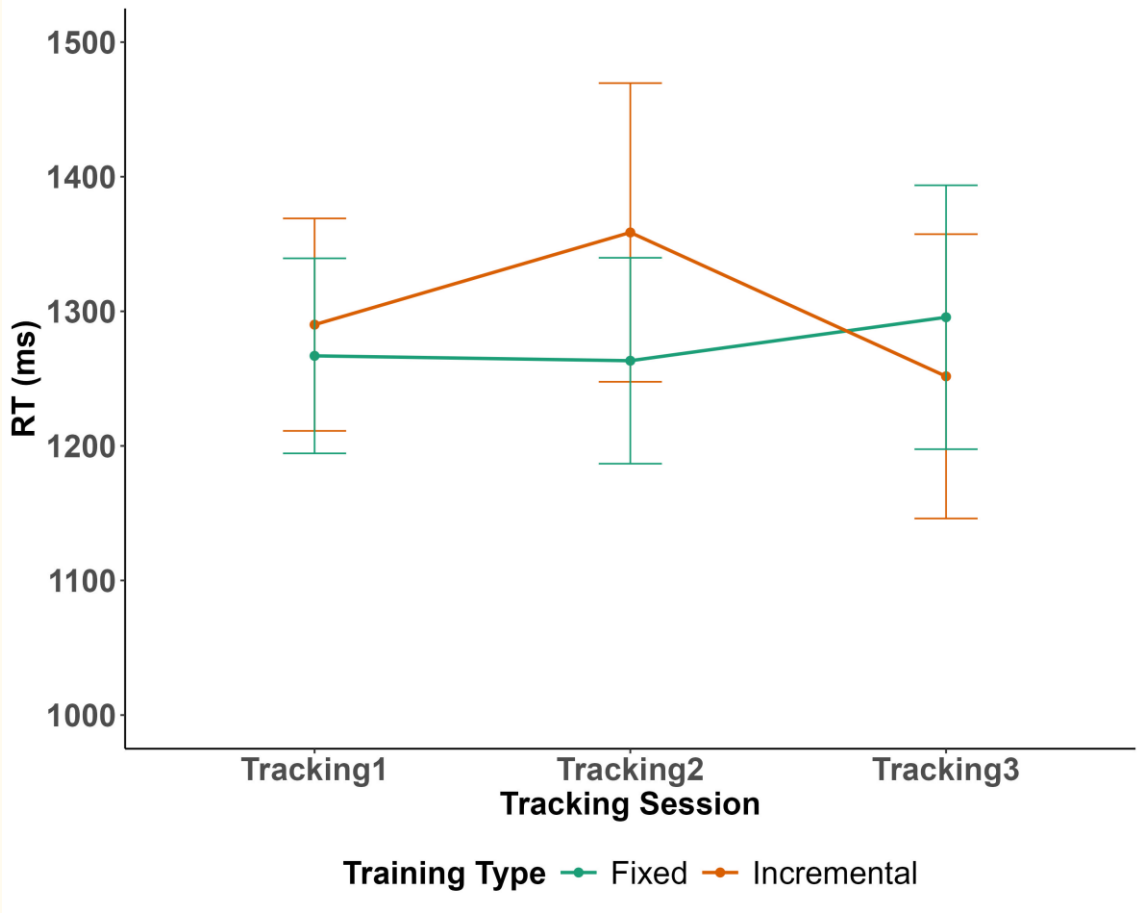
Where $Z_{x_{i,j}} = \frac{x_{i,j} - \bar{x}}{S_x}$ (S_x = sample standard deviation).

the means and sample standard deviation, i.e., $\overline{RT}$, $\overline{PC}$, SRT, and SPC, were calculated across all observed cells from the analysed experiment regardless of subjects and conditions. Therefore, positive values indicate good performance, i.e., higher accuracy with faster responses, while negative values indicate lower accuracy with longer responses. BIS values also directly express whether a group of participants performs above (BIS > 0) or below (BIS < 0) average.

Other effective measures included Rate-correct Score (RCS), Inverse Efficiency Score (IES), and Linear Integrated Speed-accuracy Score (LISAS) (Chignell et al., 2014; Liesefeld & Janczyk, 2019; Vandierendonck, 2017).

RT: training and tracking-tests



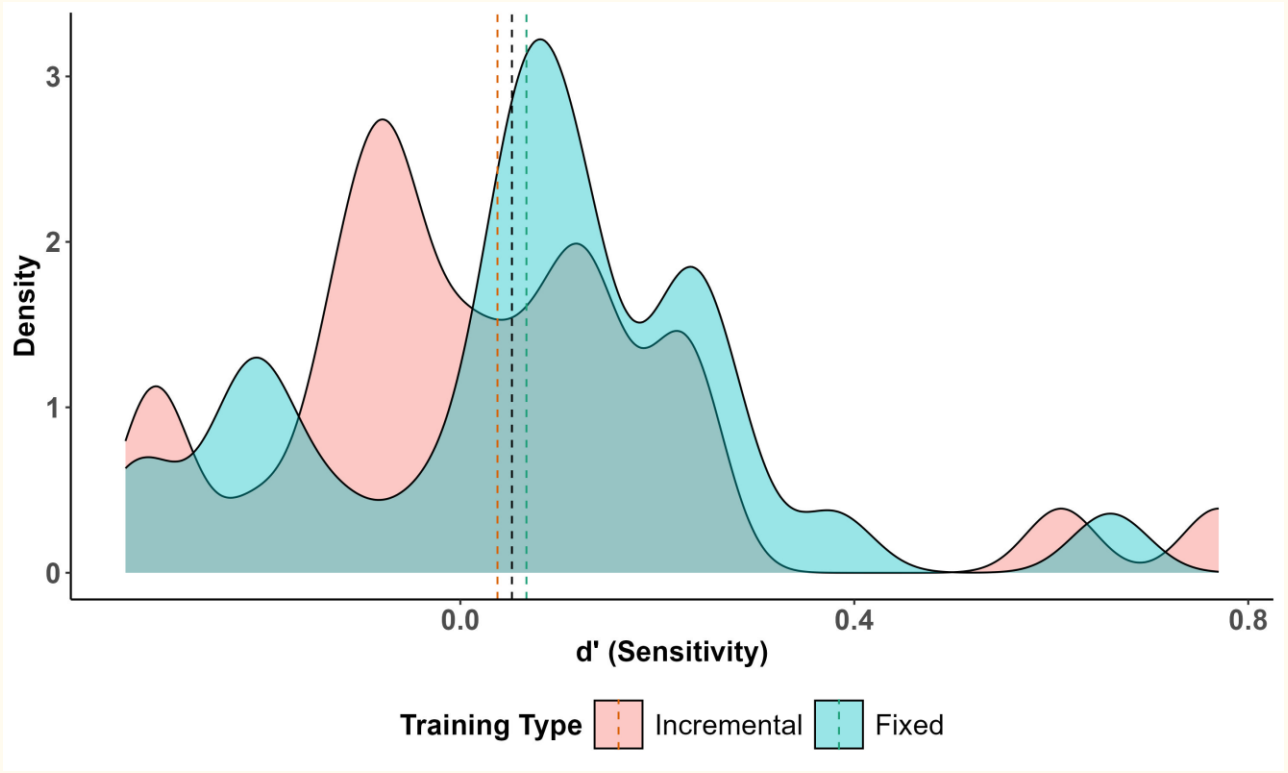


no effect of Training Type, $\chi2(1) = 0.000$, $p = .998$, Training Session, $\chi2(2) = 2.94$, $p = .23$, or Training Session x Training Type, $\chi2(2) = 2.85$, $p = .24$.

no effect of Tracking-test, $\chi2(2) = 1.58$, $p = .45$, Training Type, $\chi2(1) = 0.19$, $p = .66$, or Tracking-test x Training Type, $\chi2(2) = 0.82$, $p = .66$

Generalisation test: BIS & sensitivity (d’)

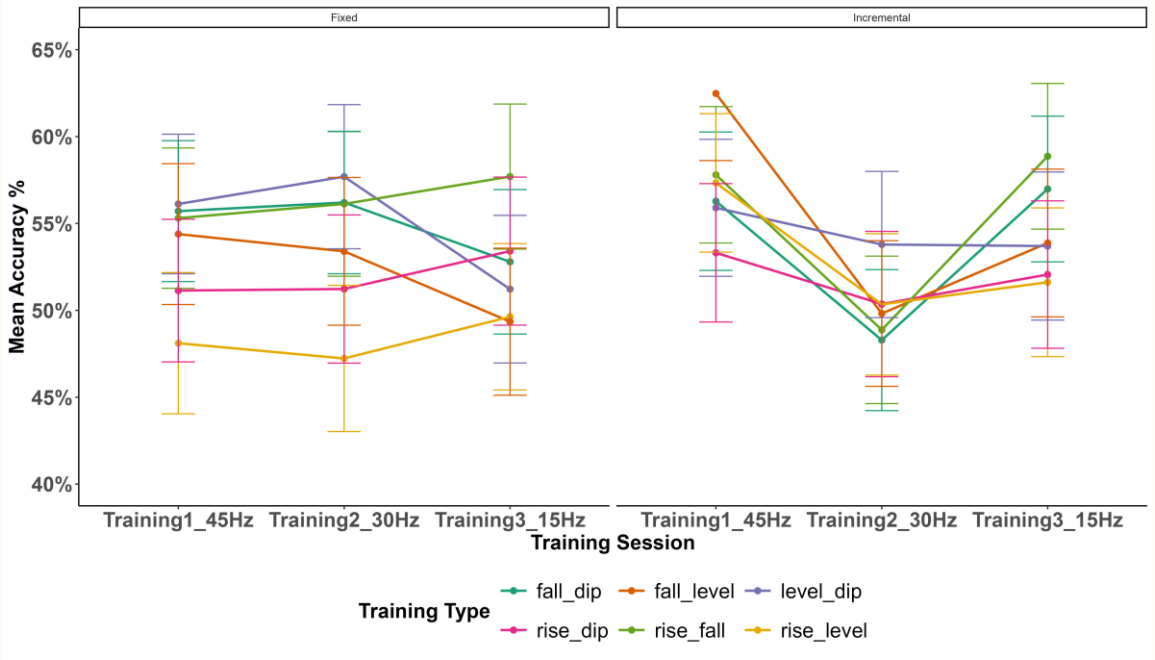
- Non-significant for BIS



- Training Type: F(1, 0.68) = 13.32, p < .001
  - Fixed > incremental

The effect of Tonal Contrast in training

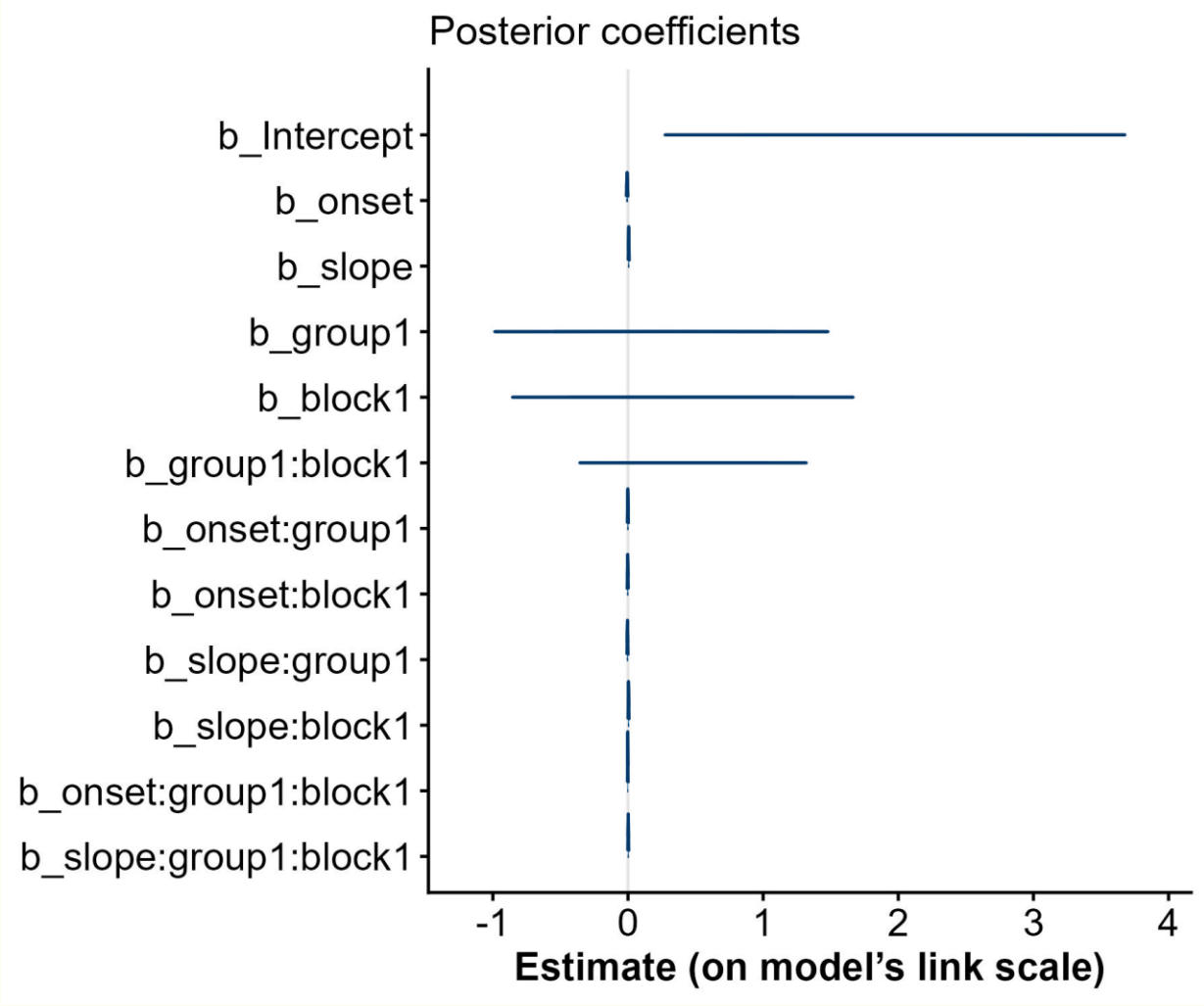
- For the effect of Tonal Contrast on response accuracy in training, model comparisons found a main effect, $\chi2(5) = 14.72$, $p = .01$. There were also marginal interaction effects of Tonal Contrast x Training Session, $\chi2(10) = 18.12$, $p = .05$, and Tonal Contrast x Training Type, $\chi2(5) = 10.53$, $p = .06$.



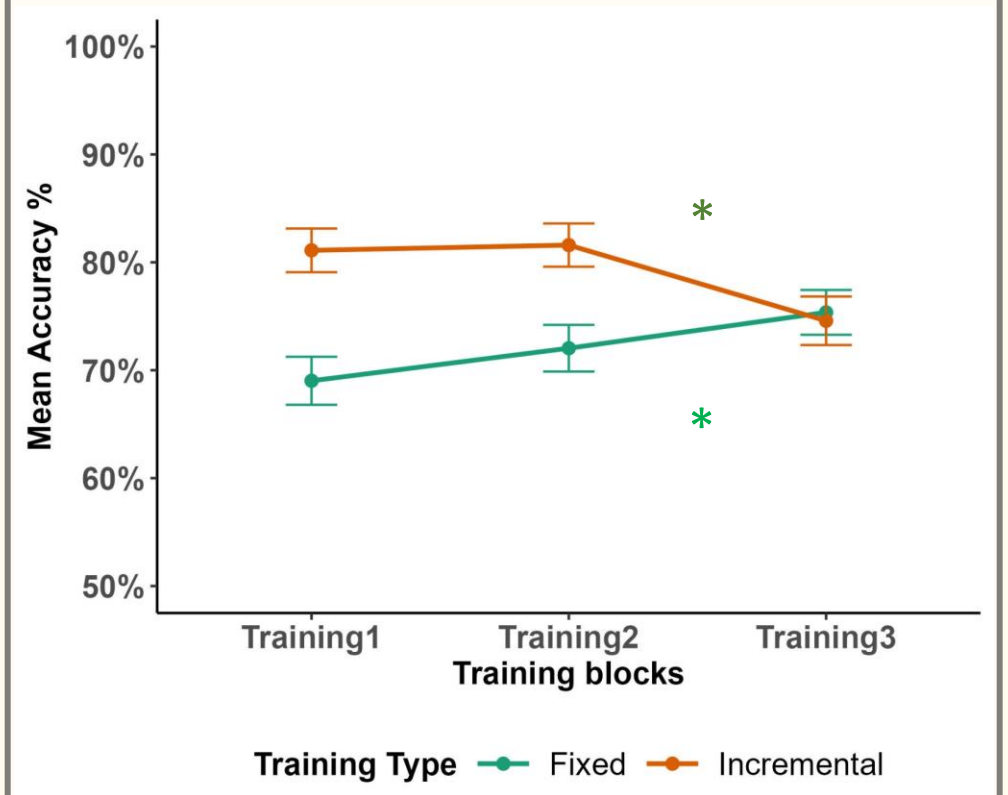
Pairwise comparisons	Test statistics
Training 1	
falling/level vs rising/dipping	*β* = 0.26, *SE* = 0.08, *p* = .02
falling/level vs rising/level	*β* = 0.24, *SE* = 0.08, *p* = .05
Training 2	
level/dip vs rising/level	*β* = 0.29, *SE* = 0.09, *p* = .01
Training 3	
falling/level vs rising/fall	*β* = -0.27, *SE* = 0.09, *p* = .02
rising/falling vs rising/level	*β* = 0.31, *SE* = 0.09, *p* = .005

Table 6-17 Pairwise EMMs test statistics for the effect of Tonal Contrast and Training Session on accuracy data for the Fixed group in training sessions (Study 5).

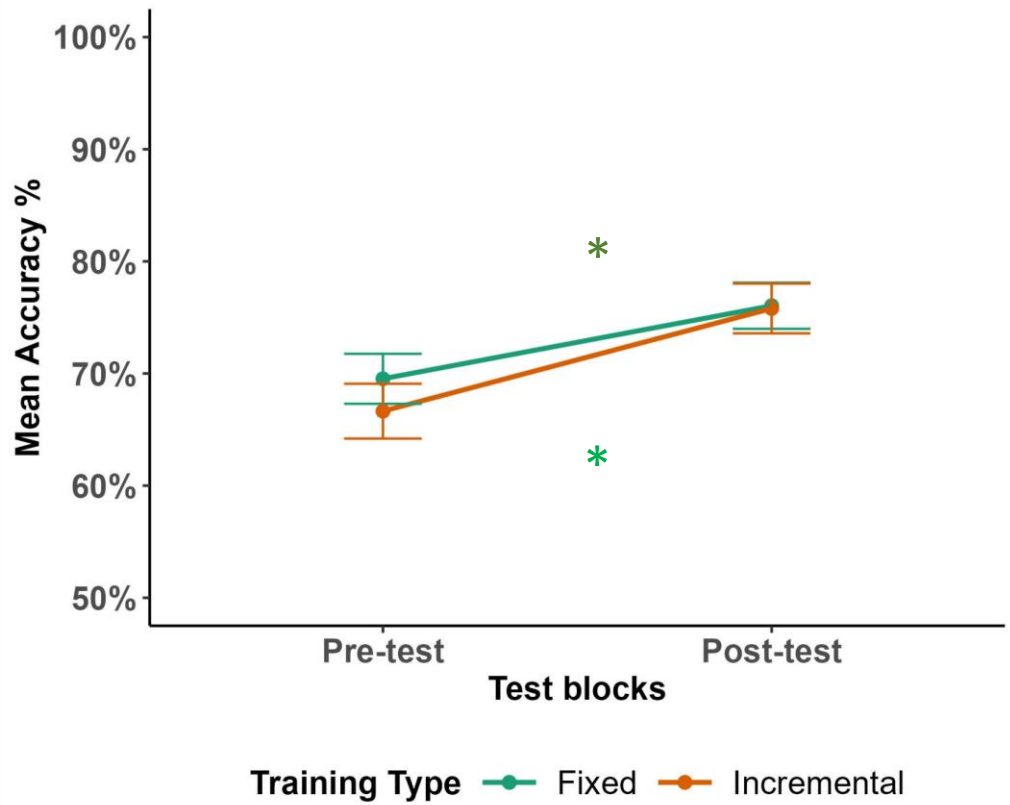
Attempted analysis with cue weighting: Bayesian analysis in pre-/post-test



Study 1 Results: Accuracy

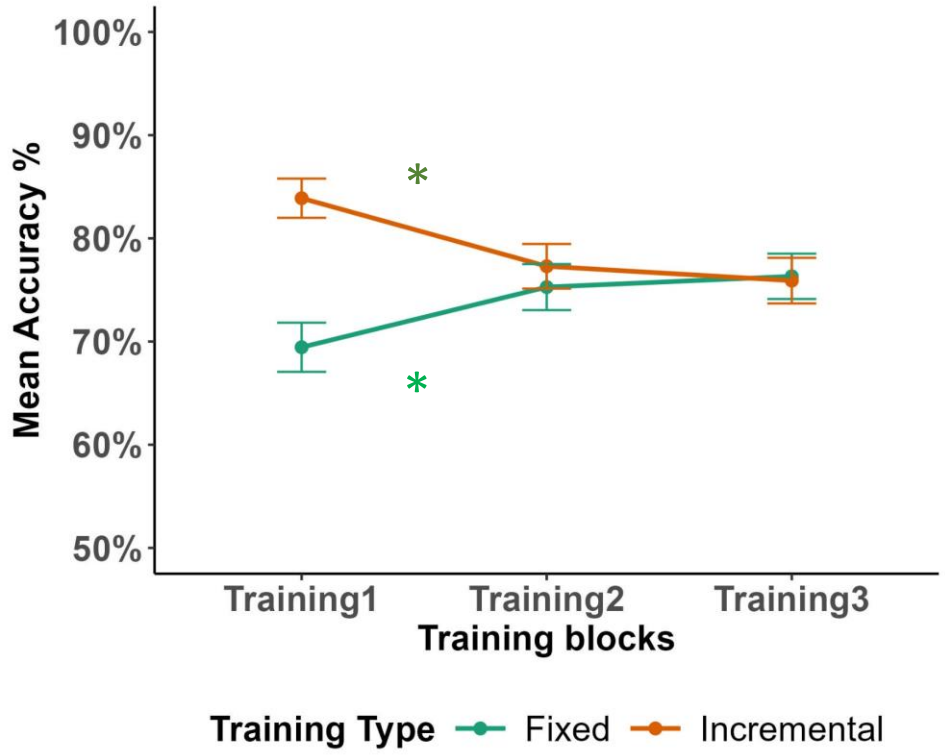


Training: Block * Training_type

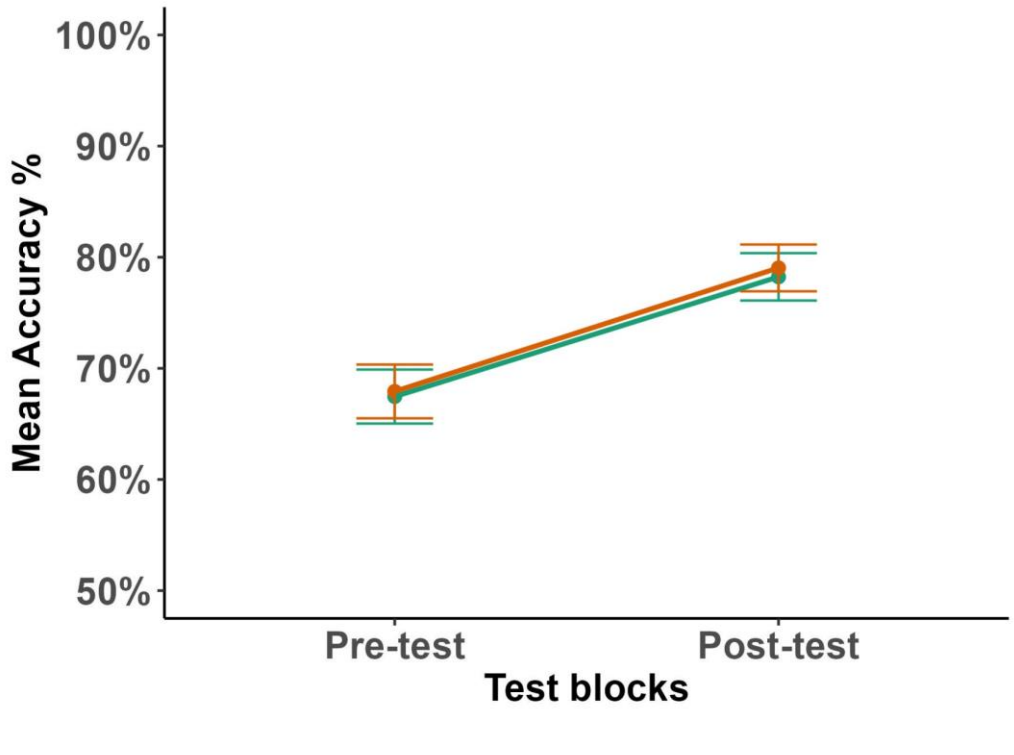


Tests: Block

Study 2 Results: Accuracy

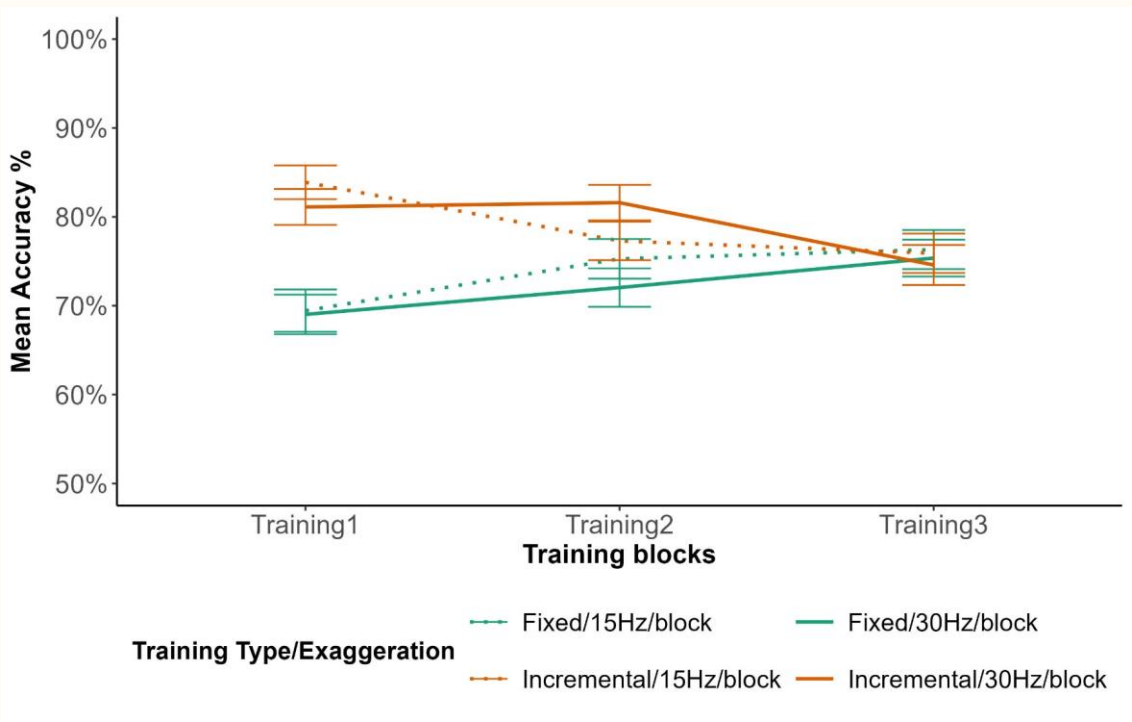


Training: Block * Training_type

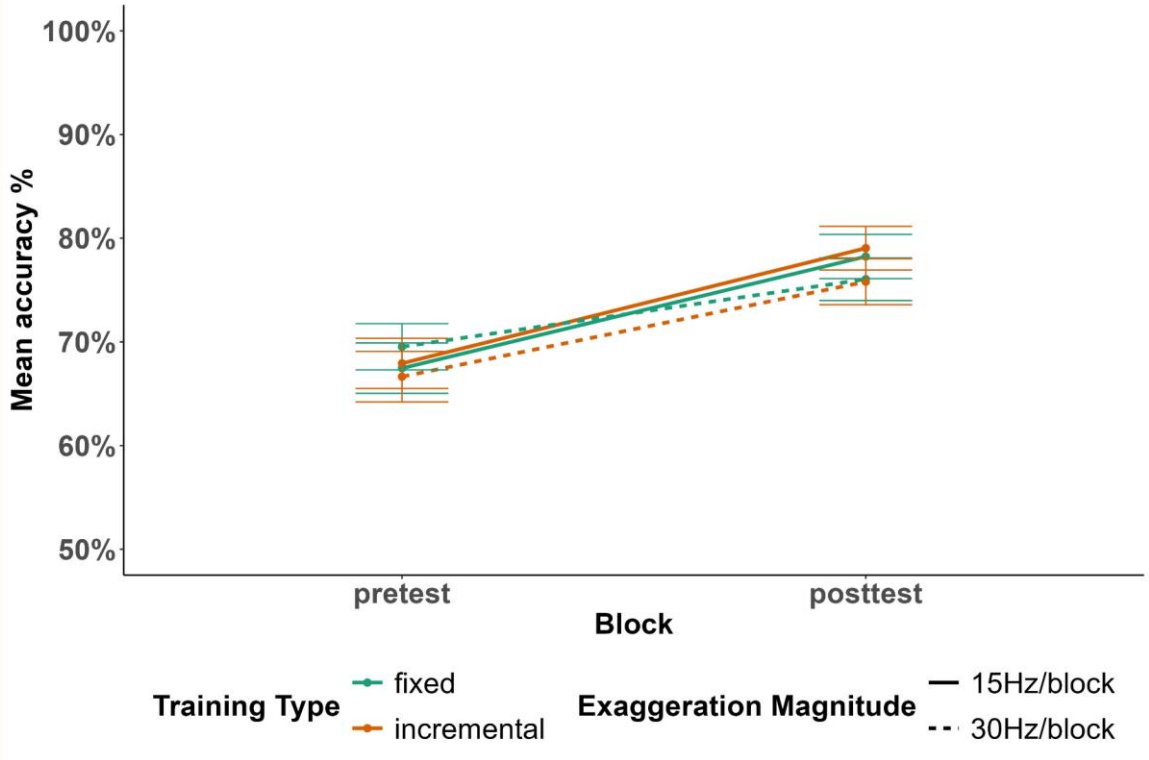


Tests: Block

Study 1 & 2 Results: Accuracy

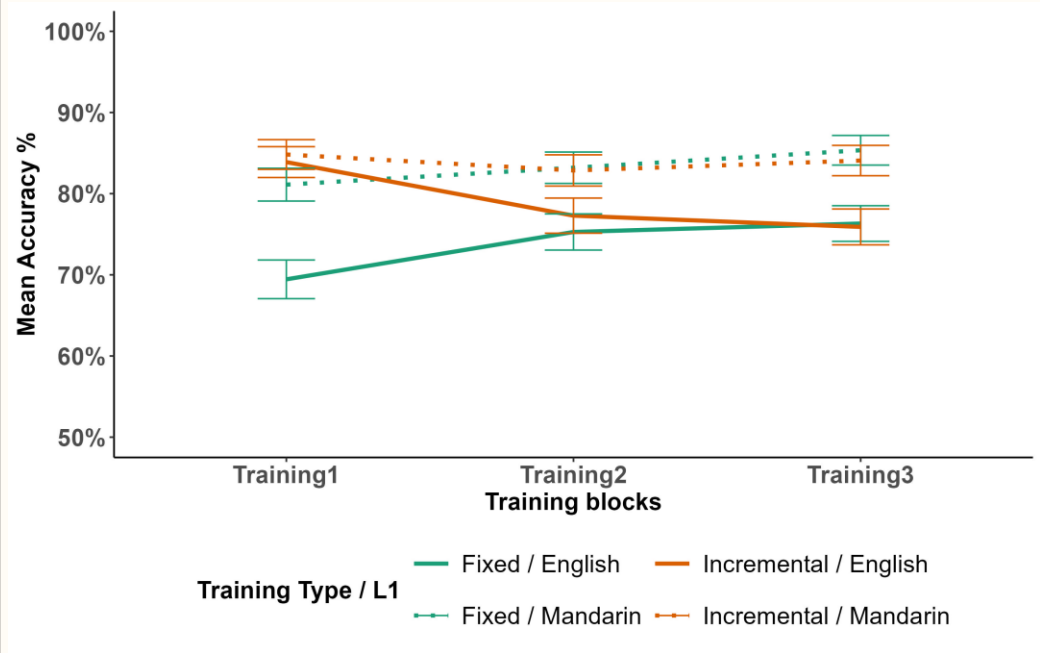


Training: no effect of Study



Tests: no effect of Study

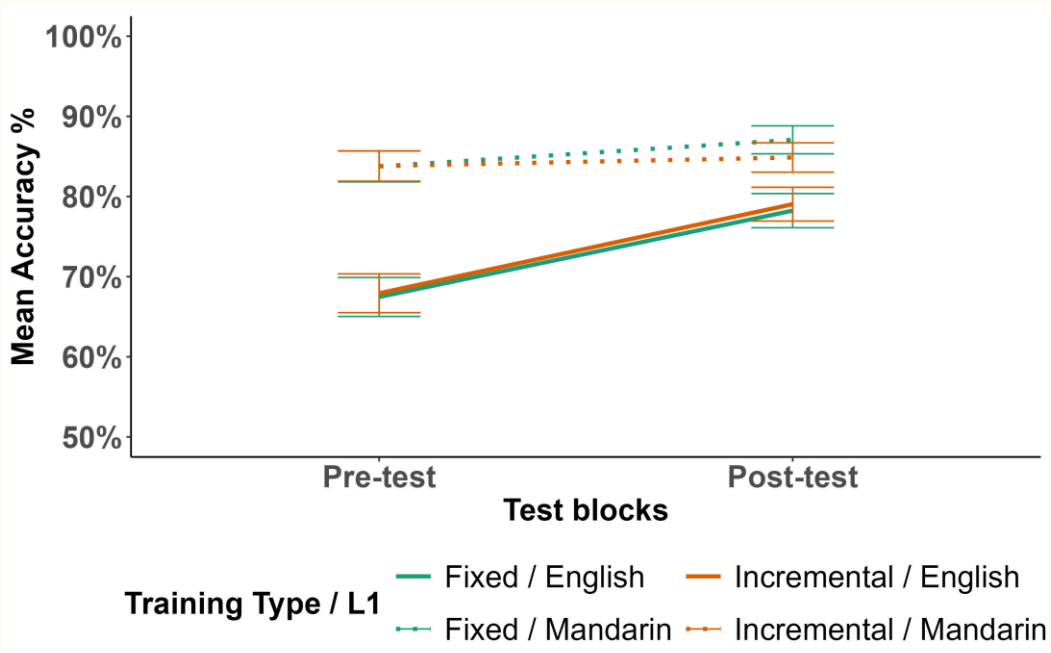
Study 2 & 3 Results: Accuracy



Training: L1 (tonal vs non-tonal)

L1 x Block x Training_type

Mandarin: fixed improved T1 to T3

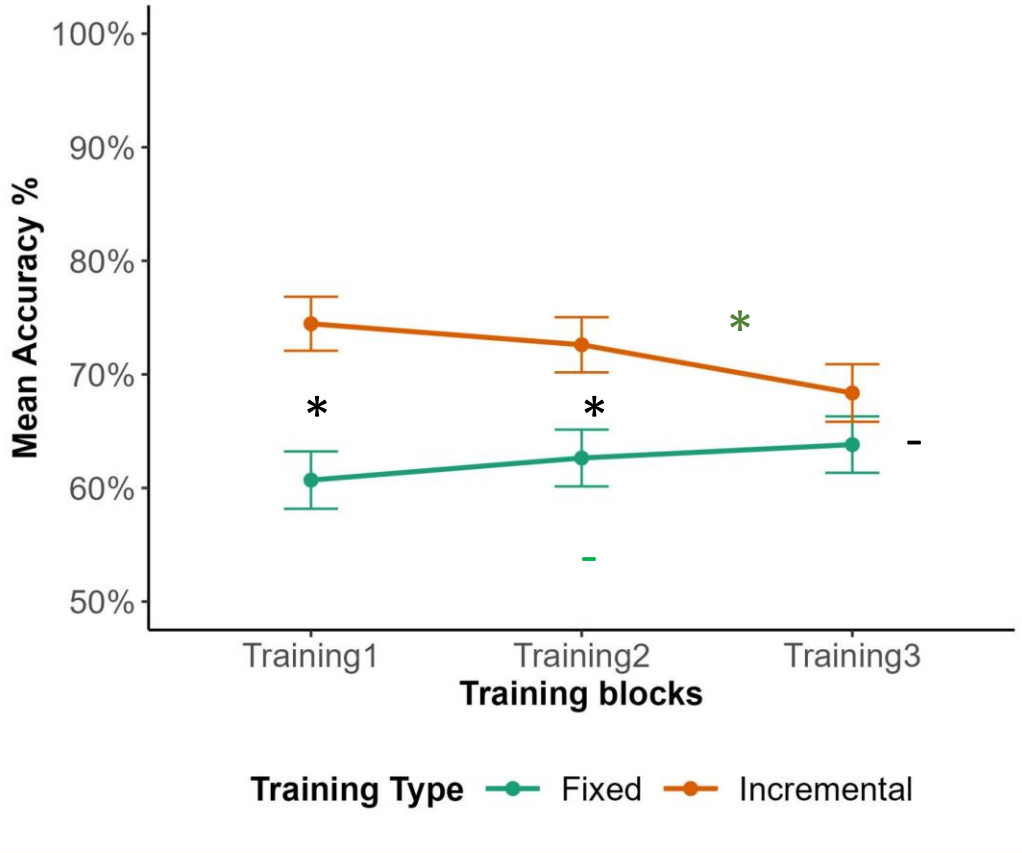


Tests: L1

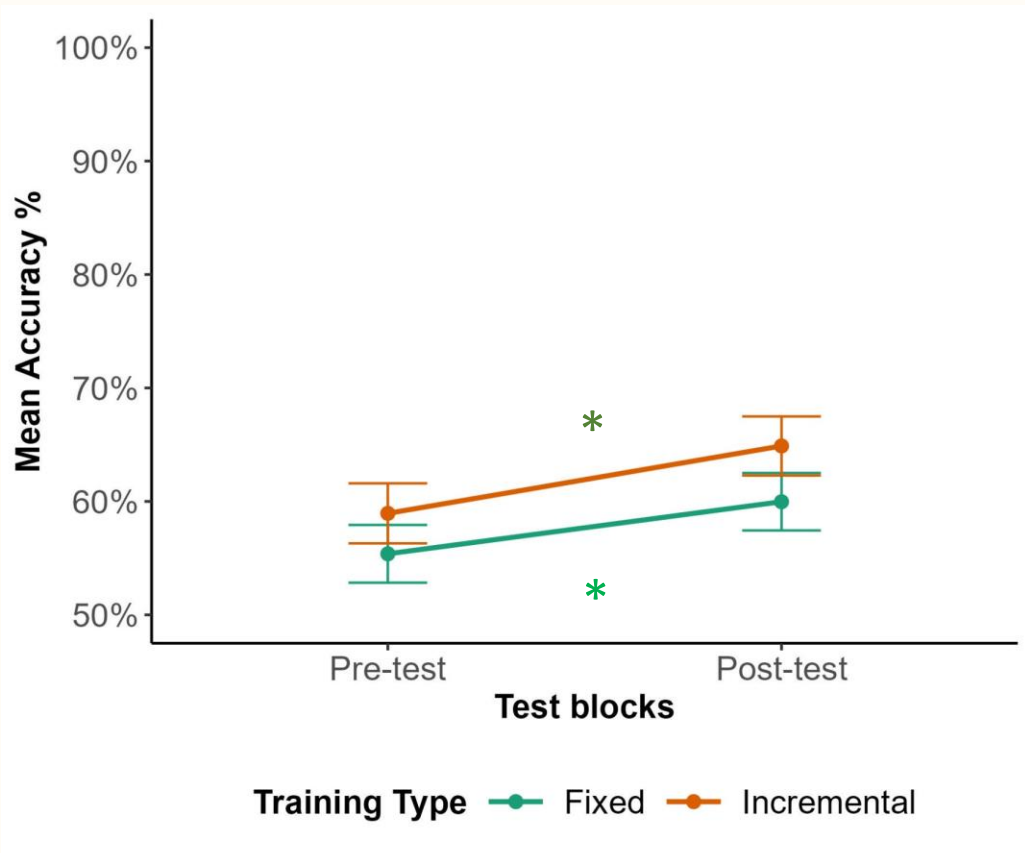
L1 x Block

Mandarin: fixed improved

Study 4 Results: Accuracy

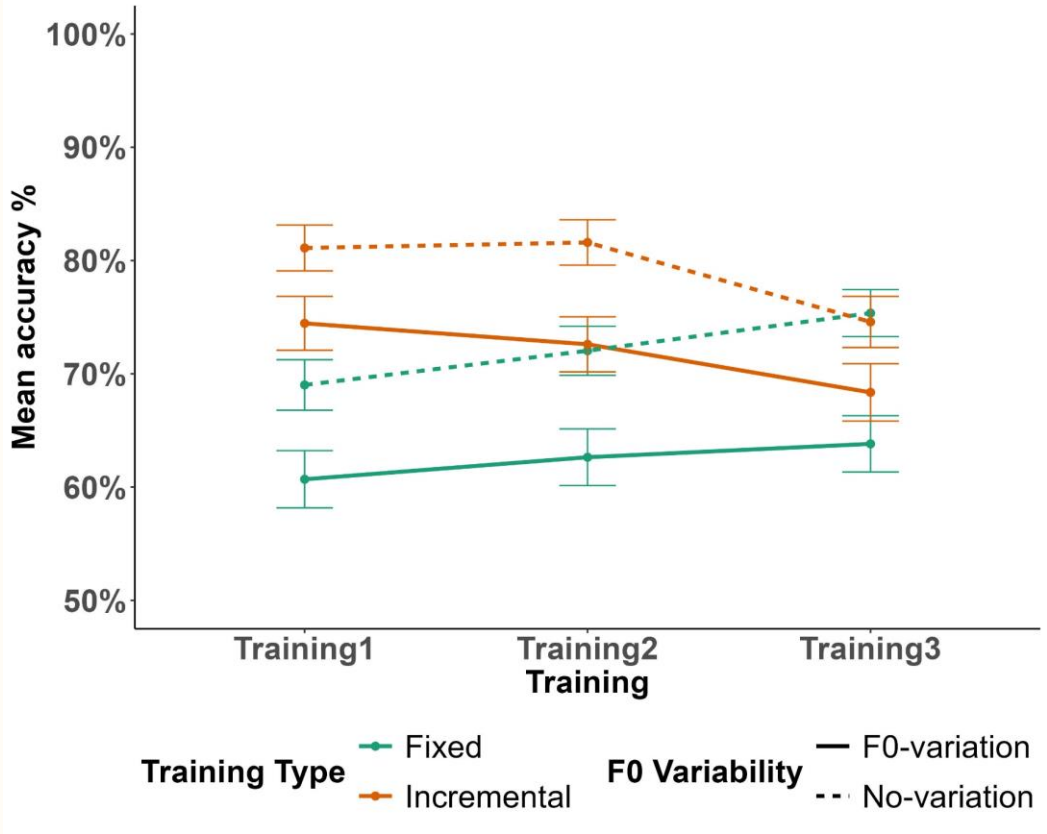


Training: Training_type, Block x Training_type

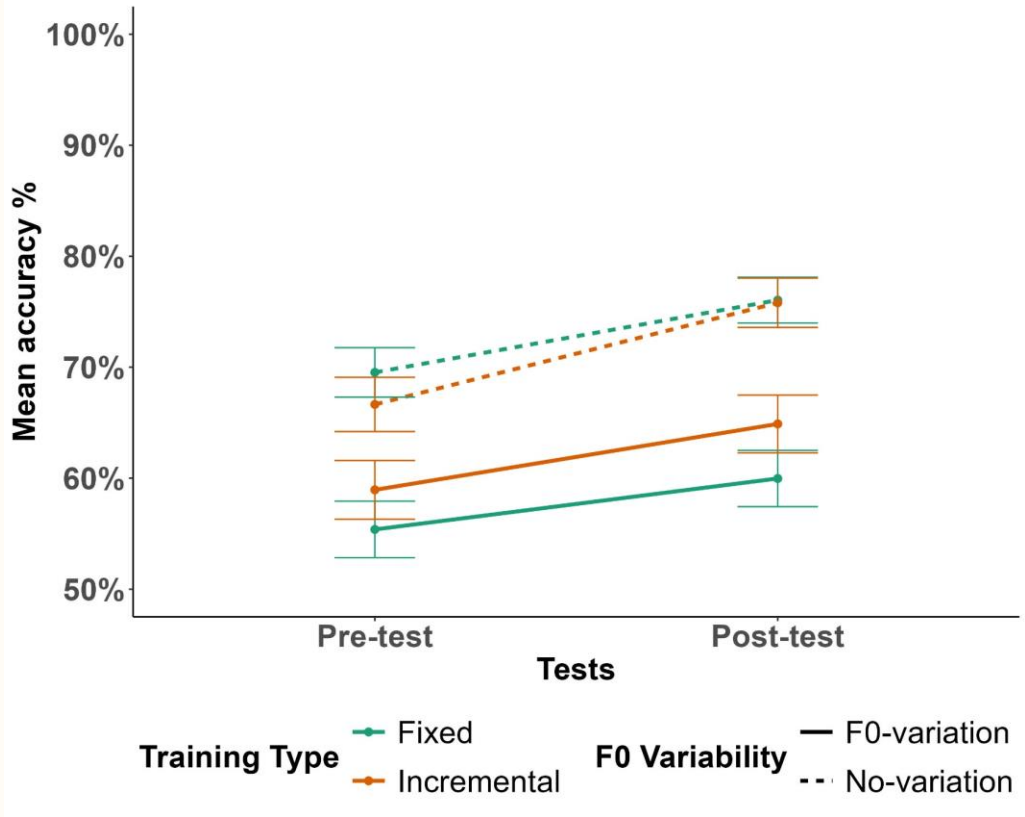


Tests: Block

Study 1 & 4 Results: Accuracy



Training: F0 Variability



Tests: F0 Variability

Training paradigms in Kondaurova and Francis (2010)

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