Knowing When You're Right: Metacognitive Accuracy in Audio-Vibrotactile Music Perception

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Background - Hearing-in-Noise

Have you ever found it challenging to hear your friend on the phone while walking down a busy, loud street?

Me too!

This ability to perceive auditory stimuli amongst background noise is a challenge for everyone, **especially individuals with hearing impairments**

- While current assistive technology can help, acoustic details are often lost [1], leading to lower quality of life and difficulty connecting with music [2 3]

Multisensory integration is a promising solution to face these challenges[4]. **Vibrotactile feedback** - which can convey pitch, rhythm, and all other elements of sound through vibration - **may serve as a supportive mechanism to improve music perception**[5]

Background - Metacognitive Accuracy

If vibrotactile feedback can improve auditory perception in noise, is the job done?

Not quite…

To successfully perceive audio signals in noise, two capacities are required:

(1) accurate perception of the sound signal
(2) the ability to evaluate whether that perception is correct

This second ability is known as **metacognitive accuracy (MA)** - the alignment between confidence and correctness

If confidence is poorly calibrated, listeners may either trust incorrect perceptions or fail to act on correct ones, **leading to inefficient communication**

Hypothesis:

Vibrotactile multisensory training will improve not only perception but also metacognitive accuracy, with greater gains in the audiotactile condition.

Methodology

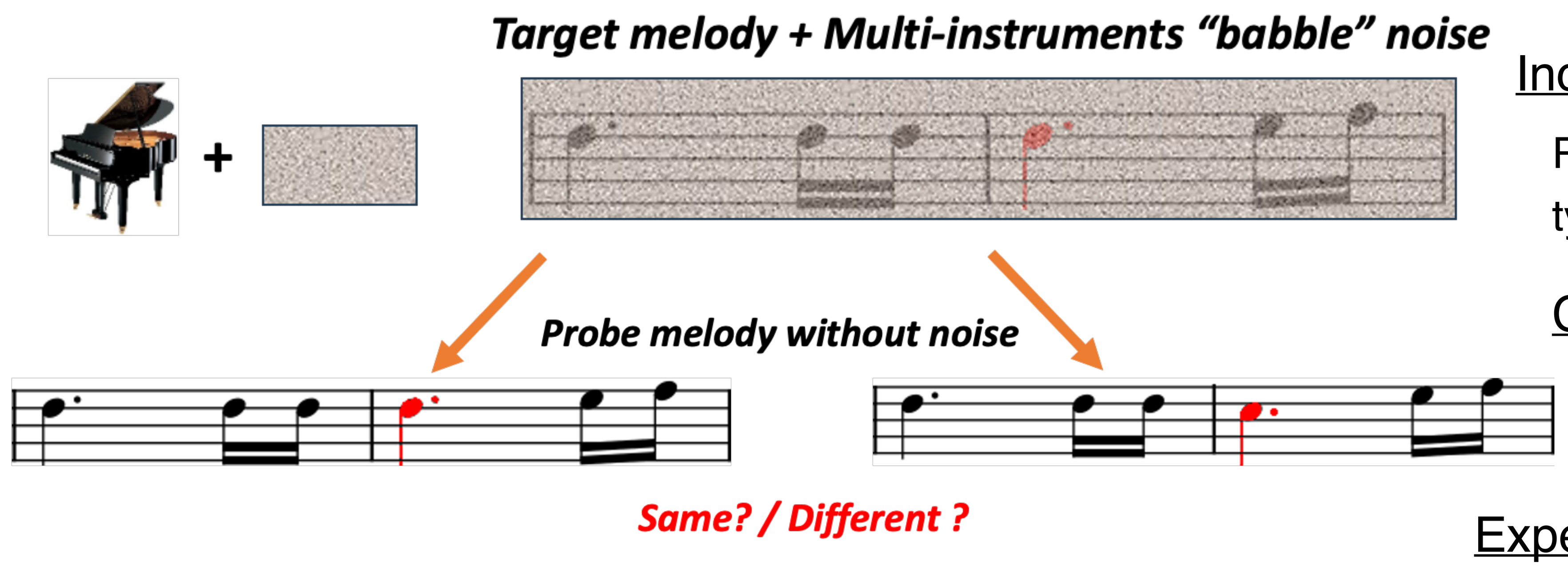
- Participants: 7 adults, normal hearing
- Multi-channel Vibrotactile Glove[6]
- Tonotopic mapping mimicking the auditory system
- 5-session training protocol

Session 1 (2hrs20mins)
Pre-Training
Establishing thresholds
EEG acquisition
Music-in-Noise testing

Sessions 2-4 (40mins)
Training
No EEG acquisition
Music-in-Noise training

Session 5 (2hrs40mins)
Post-Training
Establishing thresholds
EEG acquisition
Music-in-Noise testing

Music-in-Noise Task (MINT)[7]



- Either rhythmic or melodic alterations
- 3 conditions: Audio / Audiotactile / Tactile
- 3 SNRs (0, -3, -6)

Assessment of Metacognitive Accuracy

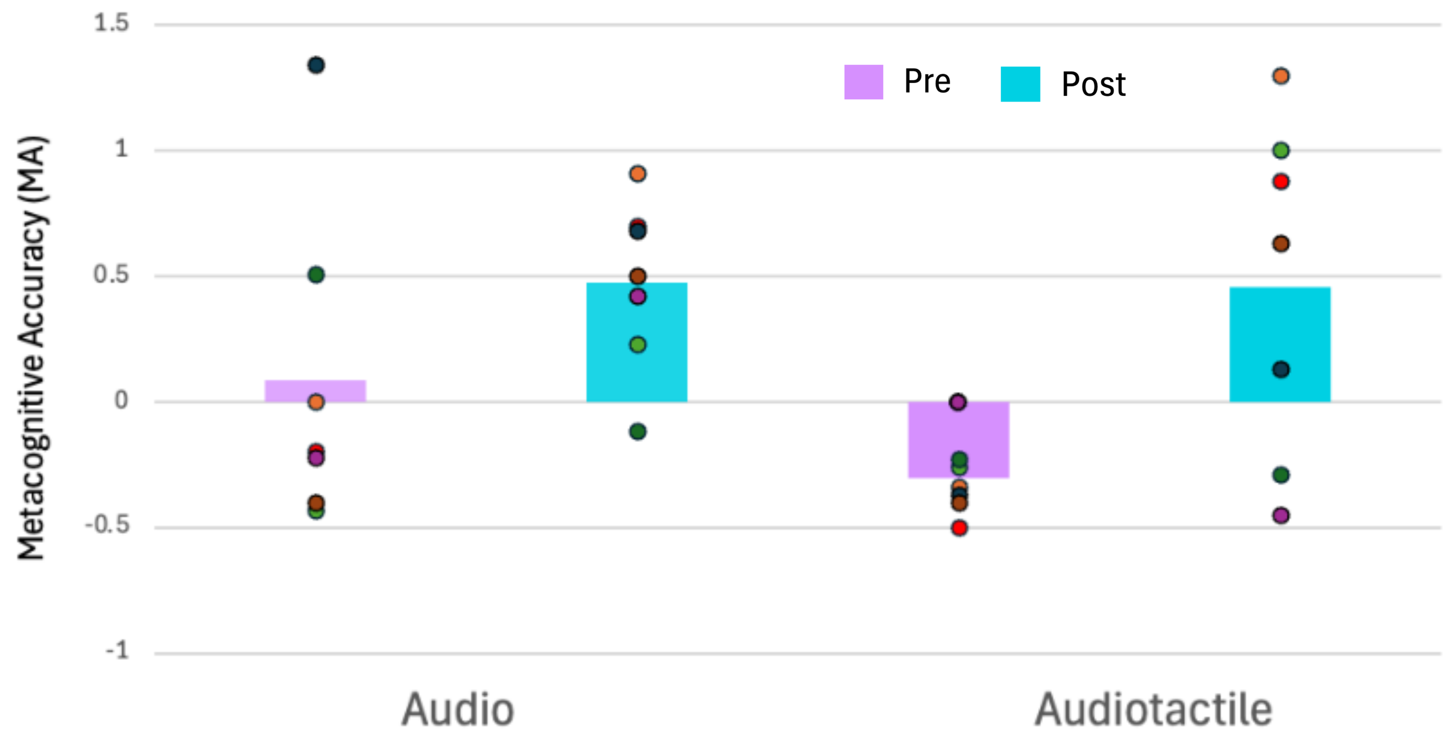
- Local confidence reports on a subset of trials (28 for test / 12 for train)
- Reported on a 1-4 ordinal scale (very low-very high confidence)

$$\text{MA} = \text{mean}(\text{conf}|\text{correct}) - \text{mean}(\text{conf}|\text{incorrect})$$

Higher values indicate greater differentiation between correct and incorrect responses, reflecting stronger confidence-accuracy alignment

Results

Changes in Metacognitive Accuracy Across Conditions n = 7



2 × 2 repeated-measures ANOVA to examine the effects of **time** and **condition** on MA:

Main effect of time: $F(1, 6) = 5.52$, $p = .057$, $\eta p^2 = .48$

- **large effect size**, approaching statistical significance
  - no significant effects of condition, or time * condition interaction

Discussion

Multisensory vibrotactile training may improve MA!

MA improvements regardless of training → domain-general?

Negative MA in pre → unfamiliarity with task?

Future studies should:

Increase sample size:

Repeated-measures designs with similar effect sizes typically require ~15-30 participants

Consider modifying the design

~6 hour protocol may have introduced fatigue and reduced motivation

Experiment with different MA metrics

As task performance increased, # of incorrect trials ↓, this makes the MA estimate more susceptible to noise

One participant had to be removed because of no MA calculated

References

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[5] Chauvette, L., Sophie Grenier, A., Albouy, P., Coffey, E., Zatorre, R., & Sharp, A. (2025). Auditory and vibrotactile interactions in perception of timbre acoustic features. *Scientific reports.*

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[7] Coffey, E. B., Arseneau-Bruneau, I., Zhang, X., & Zatorre, R. J. (2019). The Music-In-Noise Task (MINT): A tool for dissecting complex auditory perception. *Frontiers in neuroscience.*