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The role of agency in neurofeedback performance

Claire Dussard¹, Léa Pillette², Laurent Hugueville¹, Camille Jeunet^{3,*} & Nathalie George^{1,*}

¹ Sorbonne Université, Institut du Cerveau - Paris Brain Institute - ICM, Inserm, CNRS, APHP, Experimental Neurosurgery team, Hôpital de la Pitié Salpêtrière, Paris, France

² Univ. Rennes, CNRS, IRISA, UMR 6074, F-35000 Rennes

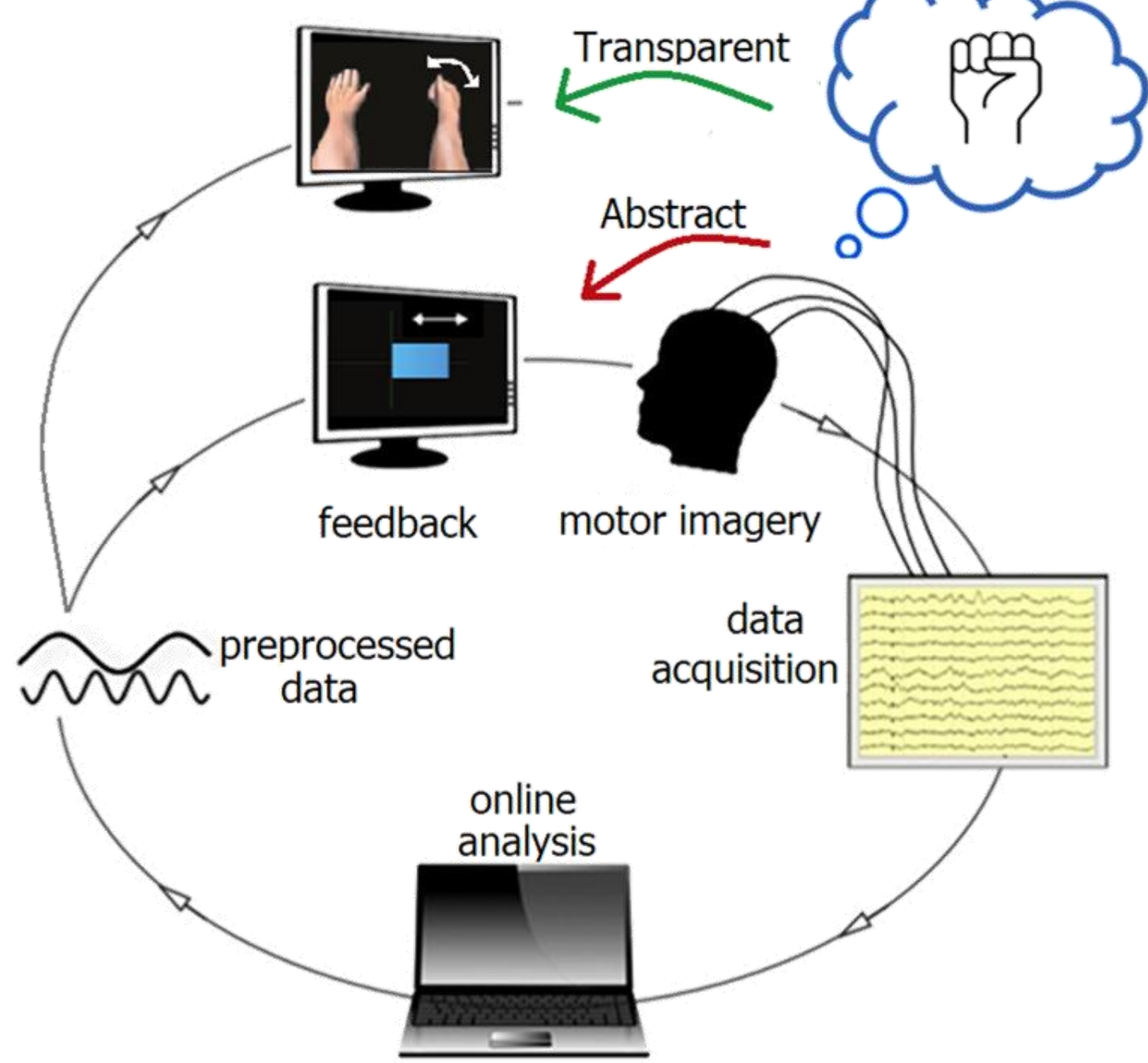
³ Univ. Bordeaux, CNRS, EPHE, INCIA, UMR5287 F-33000 Bordeaux; * : co-last authors



INTRODUCTION

Motor Imagery Neurofeedback (MI-NF) trains participants to voluntarily **reduce sensorimotor (SMR) activity by imagining movements**. Feedback (FB) is central to NF learning and improves SMR modulation relative to unsupervised MI [1]. Still, up to 38% of NF participants struggle to modulate the targeted activity [2].

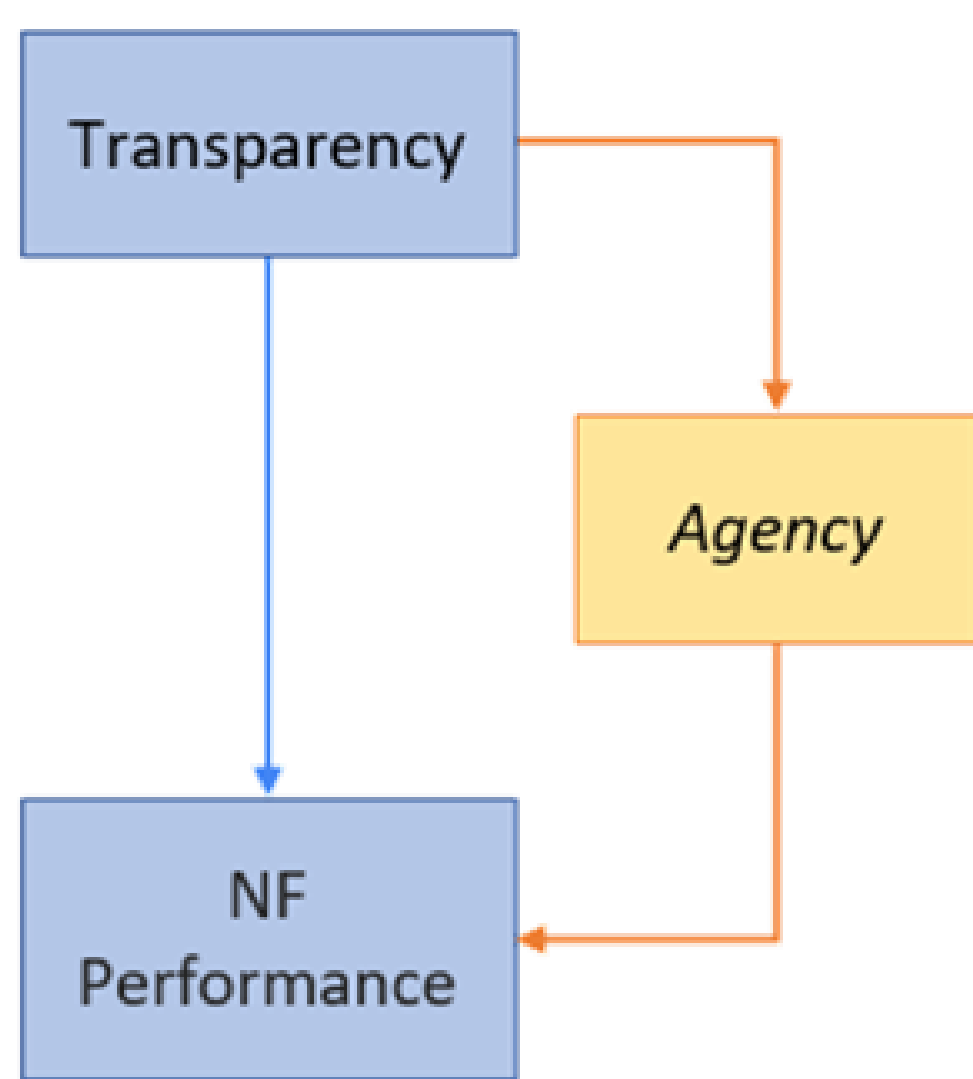
Most NF studies feature abstract FB, which obscures the causal link between MI and FB. Perceiving this link is crucial to feel control, i.e: **agency over feedback movements** in the task.



We focused on improving task-FB transparency [3] in a MI-NF task.

HYPOTHESIS:

- **FB transparency promotes agency.**
- This in turn **yields improved NF performance**, by facilitating kinesthetic MI and NF feeling of control.



METHODS

We designed 3 different feedbacks:

- 1) Pendulum** **(2) Virtual hand** **(3) Virtual hand+vibrations**



>>>>> Transparency level >>>>>

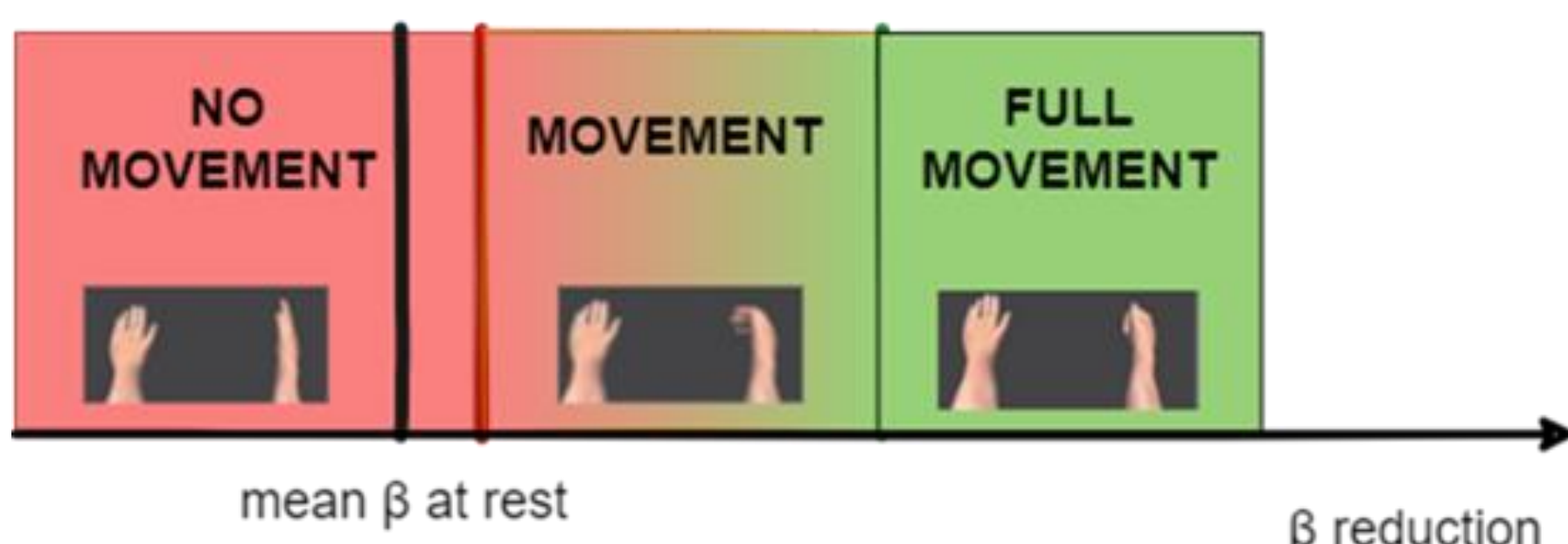
25 healthy subjects tested the 3 feedback conditions in 1 MI-NF session.

Electro-Encephalographic (EEG) activity was recorded from 32 electrodes (actiChamp plus; SR = 1kHz; DC-280Hz; reference electrode: Fz).

Feedback was based on **8-30Hz power (β band)** on **C3 electrode** computed with OpenViBE (with Laplacian transform of C3 EEG signal) [4].

β desynchronization was conveyed by feedback movement amplitude:

-10% β -55% β



Each participant performed 2 runs of five trials per condition.

Measures (23 participants analyzed)

1. NF performance

Median power in 8-30Hz band on C3 relative to reference level

2. Sense of agency

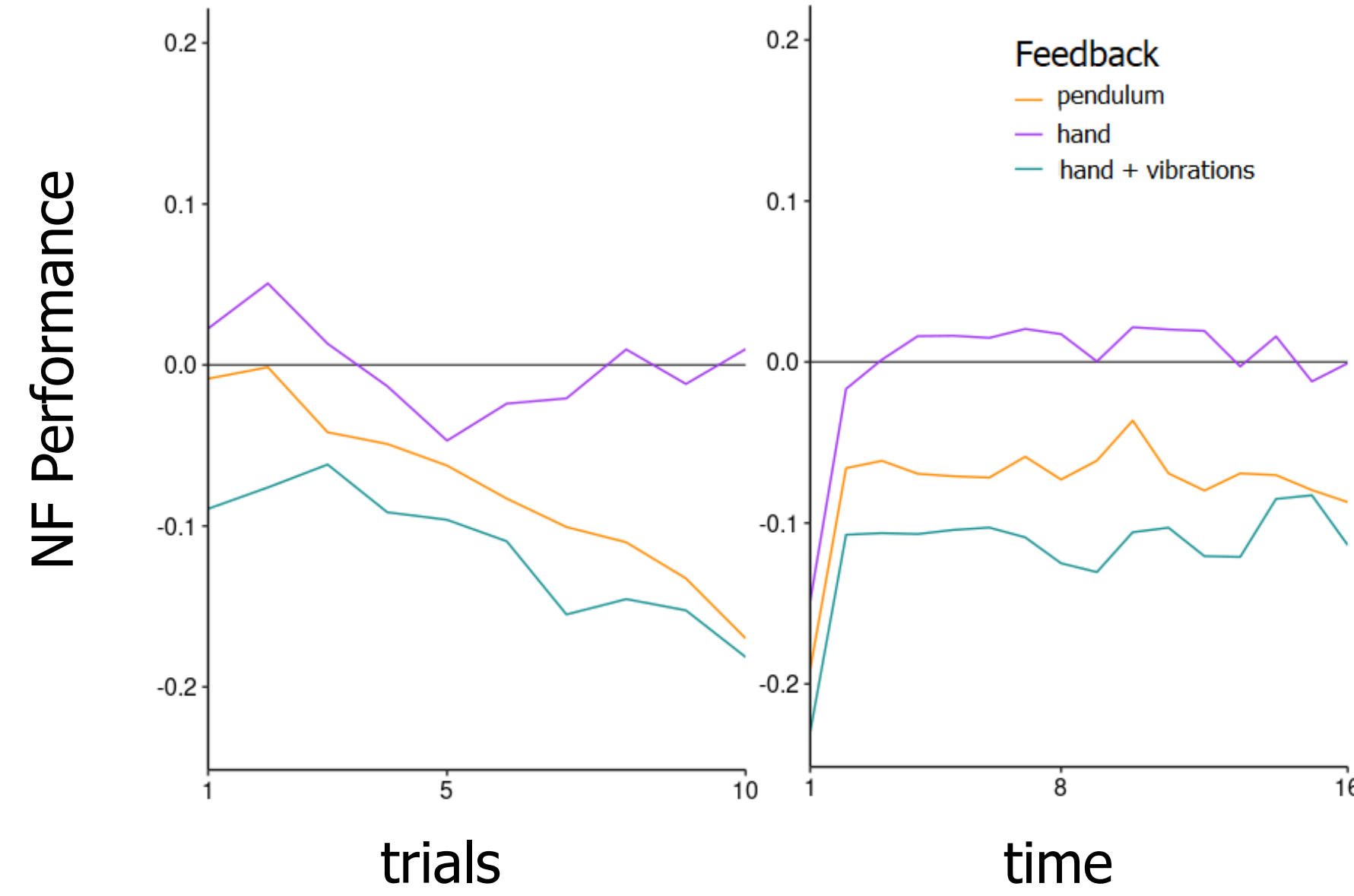
Likert scale (twice per feedback condition)

3. Event-related modulation

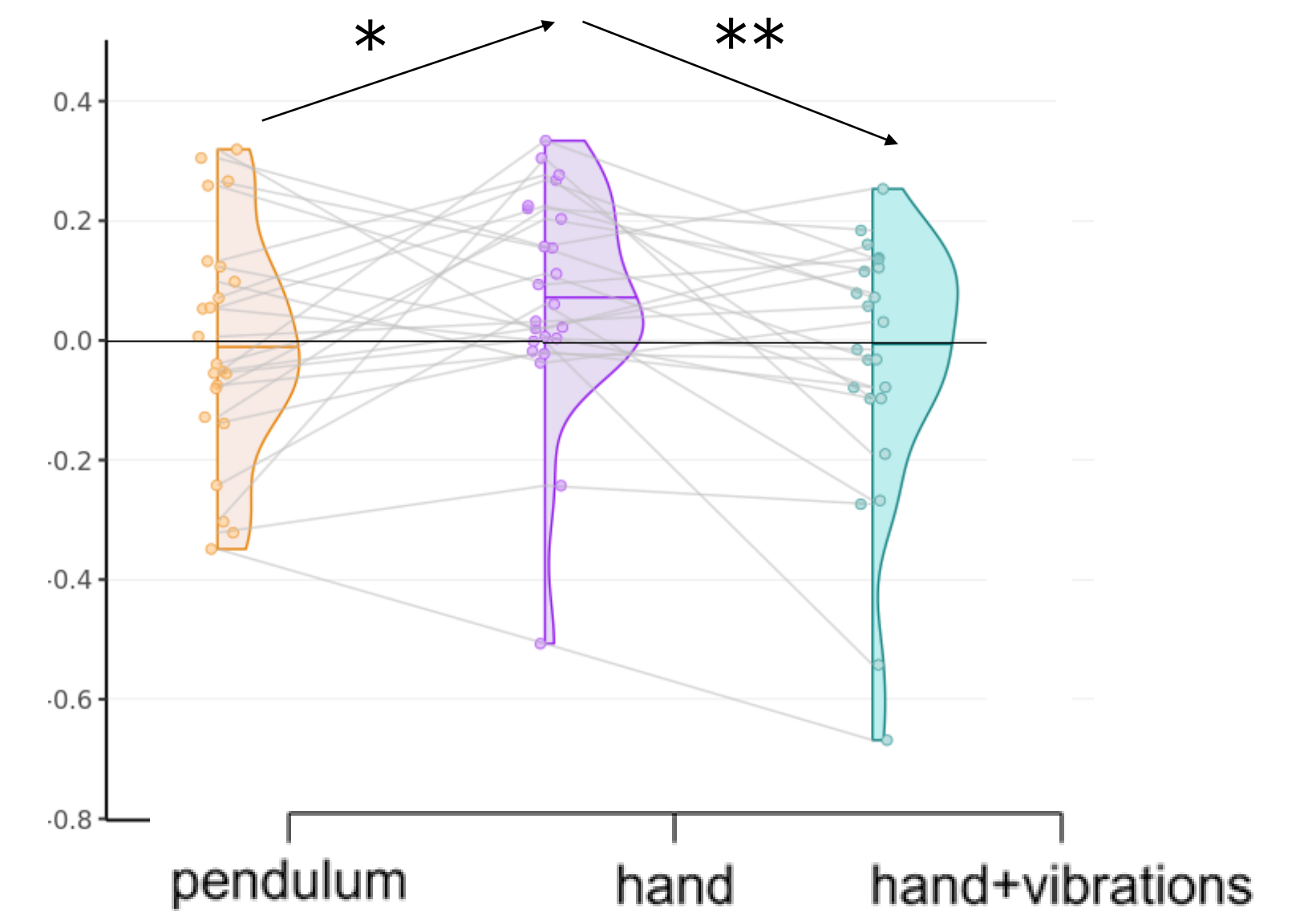
$$ERD_{C3_{8-30Hz}} = \log_{10} \left(\frac{\text{mean_power_NF_trial}}{\text{mean_power_baseline}} \right)$$

RESULTS

A. Transparency & NF performance



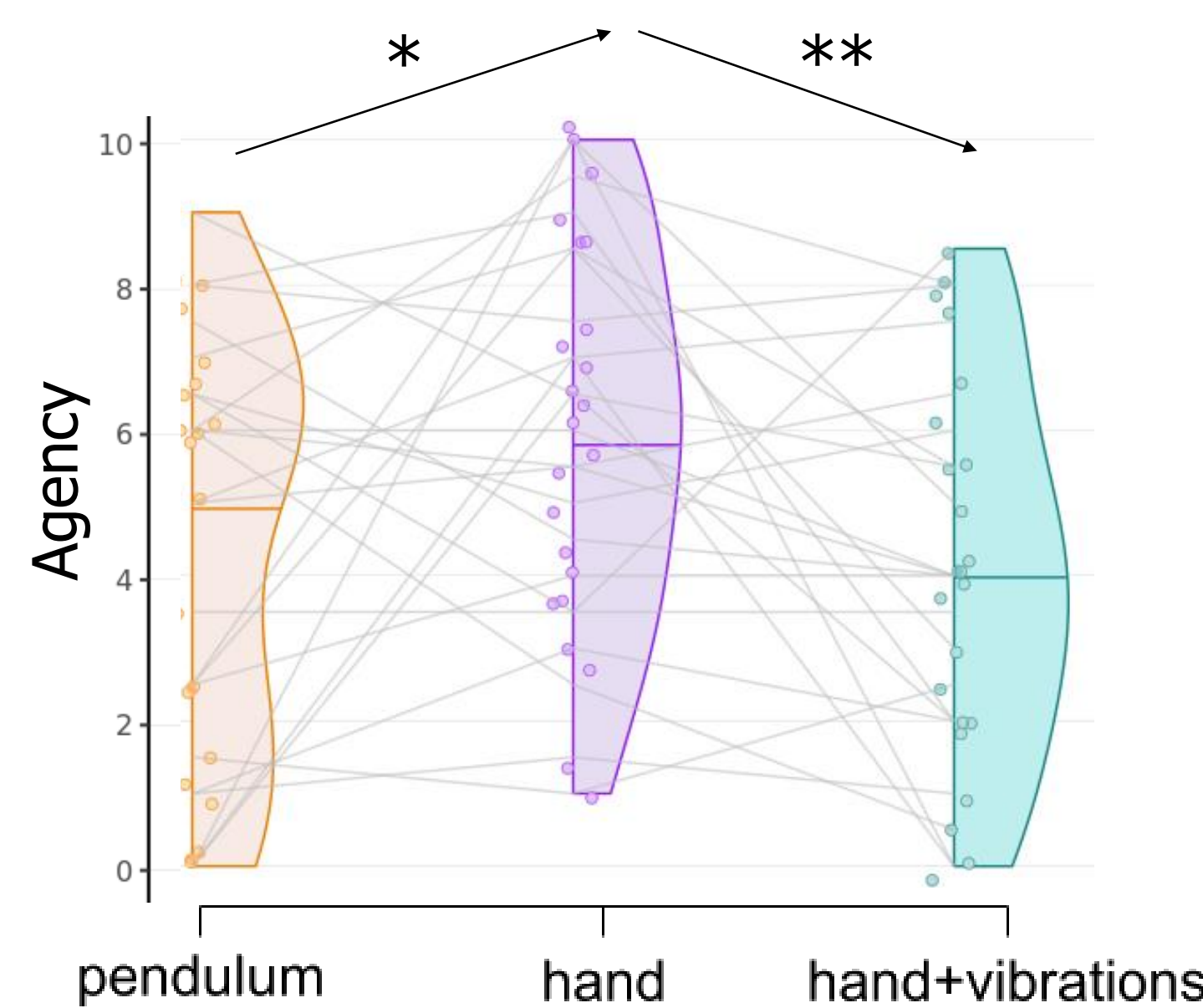
$F(2,44) = 3.9$; $p = 0.03$; $\eta^2 = 0.1$



B. Transparency & agency

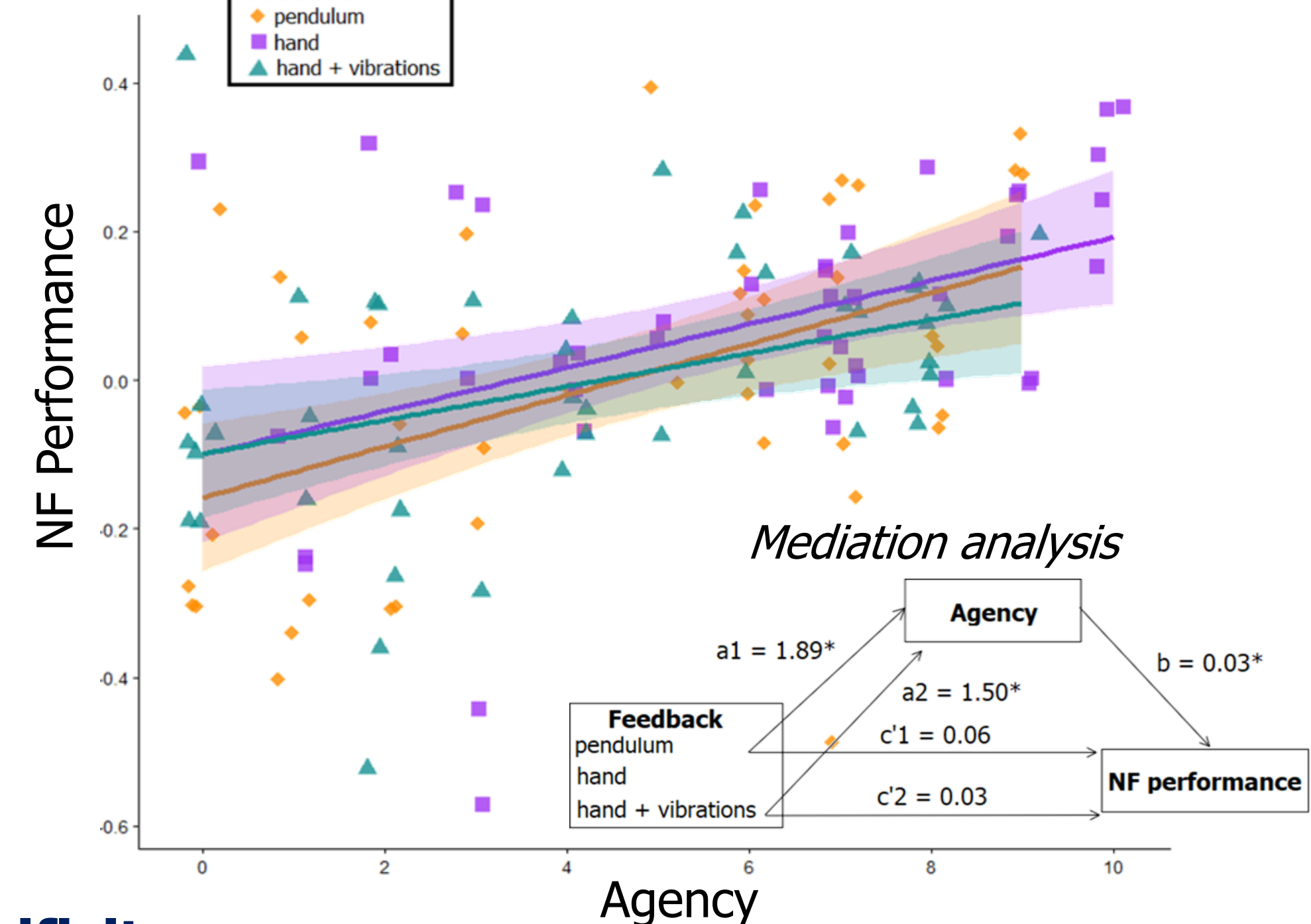
$F(2,44) = 4.36$; $p = 0.02$; $\eta^2 = 0.12$

"I felt like I was controlling the virtual hand/pendulum"

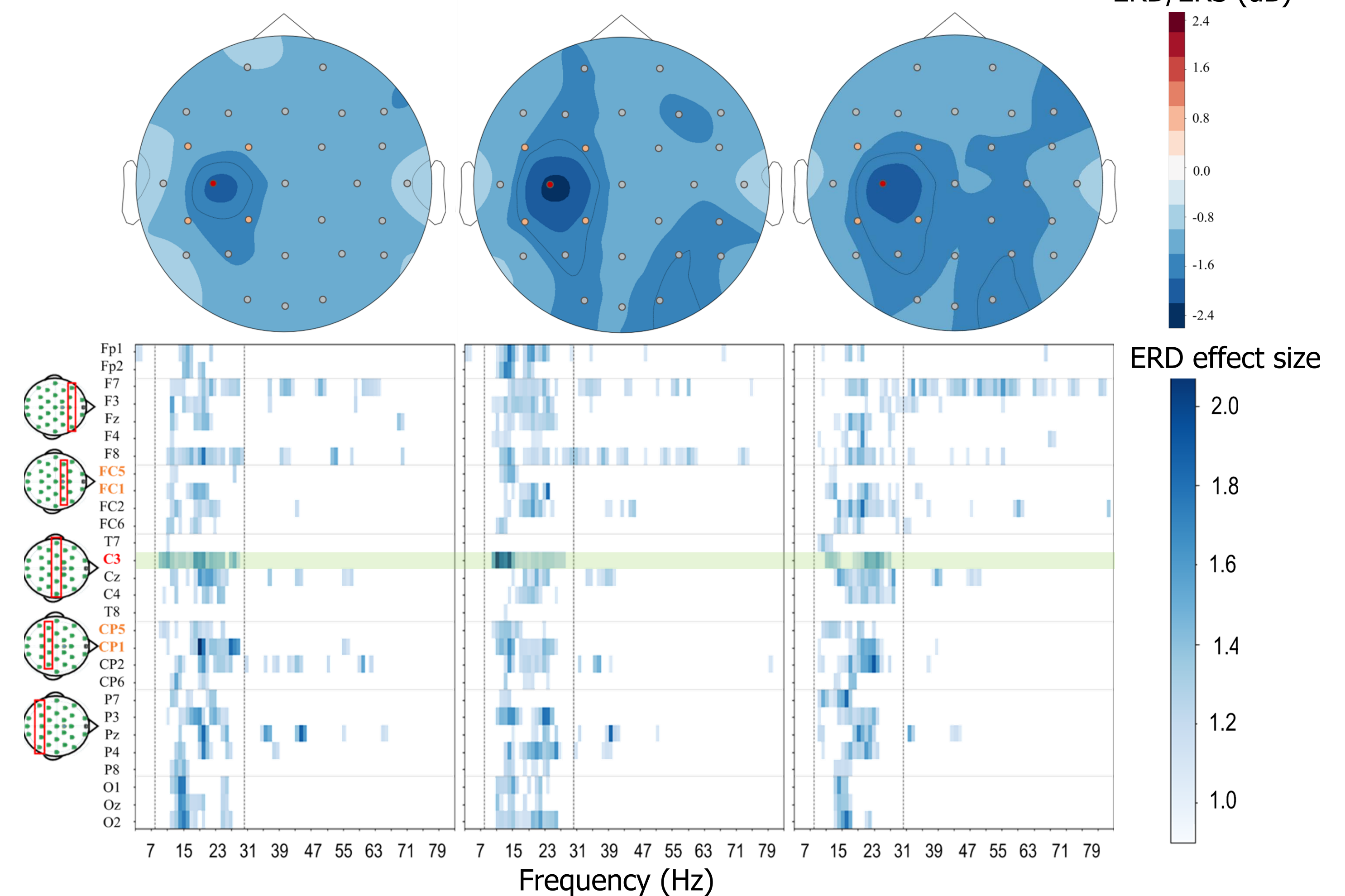


C. NF performance & agency

$r(44) = 0.49$; $r(44) = 0.44$; $r(44) = 0.37$ (all $ps < 0.01$)



E. Transparency & modulation specificity



DISCUSSION/CONCLUSION

1. Visual feedback transparency increased NF performance.
 - Relates to previous studies [5,6].
 2. The additional vibrations degraded NF performance.
 - Contradictory to previous findings [7].
 - May be due to visuo-tactile asynchrony.
 3. Agency fully mediated the effect of FB on performance, concurring with [8].
 4. Virtual hand feedback yielded a more focal ERD peaking between 12 to 15Hz over left motor cortex.
- Designing feedback that fosters **agency** may be key to develop better **NF protocols** and increase the proportion of **NF responders**.

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