Introducing the Use of Thermal Neurofeedback

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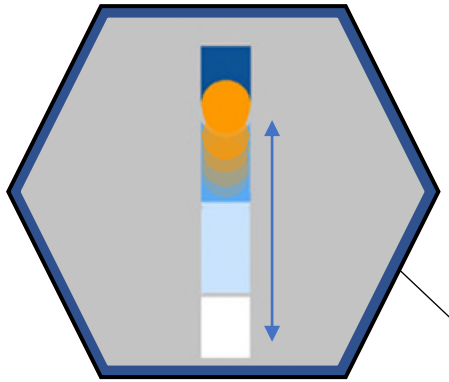
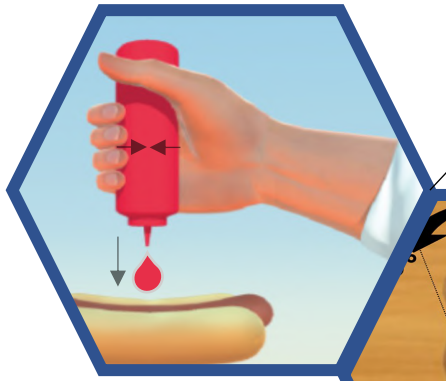
Introduction: Neurofeedback modalities

FEEDBACK MODALITIES

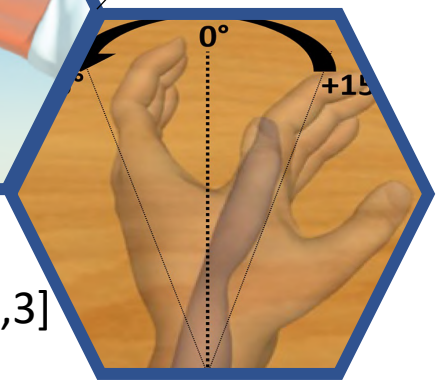
Visual

Gauge [1]





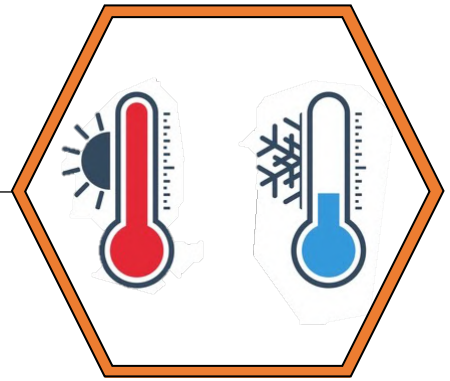
Embodied hands [2,3]



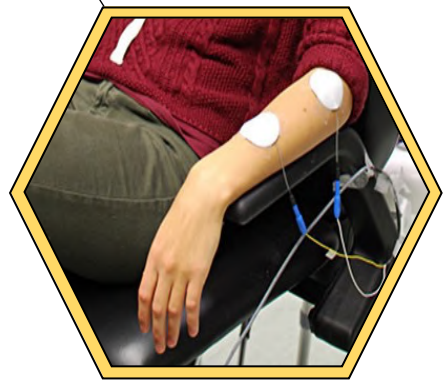
Haptic

Vibrotactile [3]

Thermal?



Force [4]

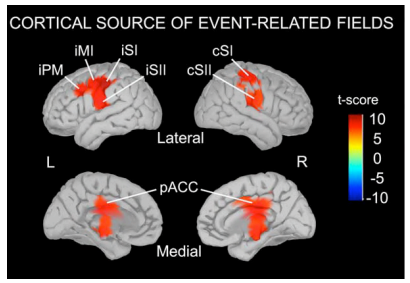


FES [4]

[1] Lioi, et al. (2020) [2] Herrera Altamira, et al. (2023) [3] Le Franc, et al. (2020) [4] Guggenberger, et al. (2020)

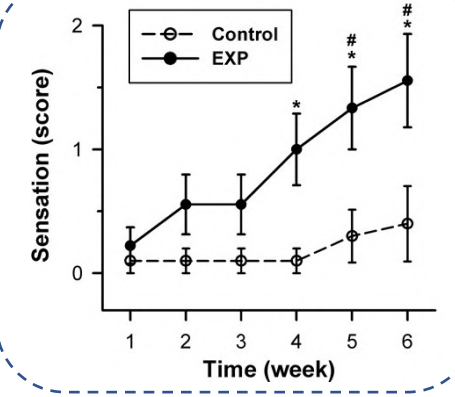
Introduction: rationale for thermal feedback

- ✓ Activates **sensorimotor areas** [5,6] and overall **lager areas** than tactile or mechanical stimulation [7,8]



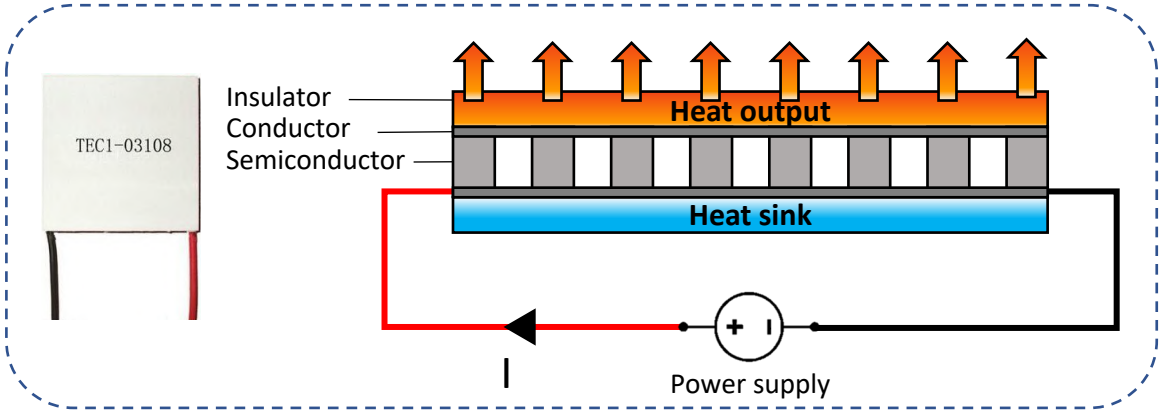
[6]

- ✓ Benefits post-stroke sensorimotor recovery [9,10]



[9]

- ✓ Convenient: Peltier cells
  - Affordable & easy to use



[5] Brown, et al. (2011) [6] An, et al. (2018) [7] Davis, et al. (1998) [8] Gelnar, et al. (1999) [9] Chen, et al. (2005) [10] Wu, et al. (2010)

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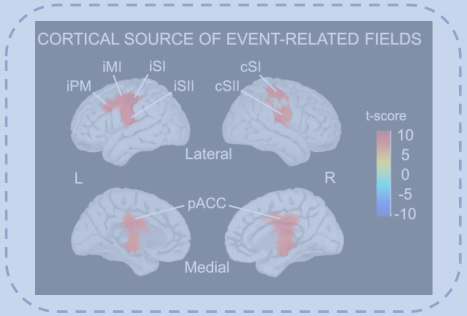
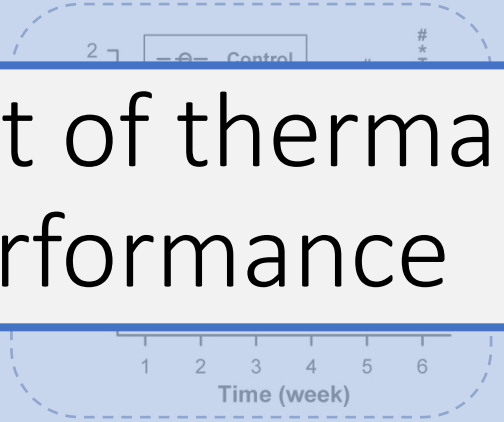


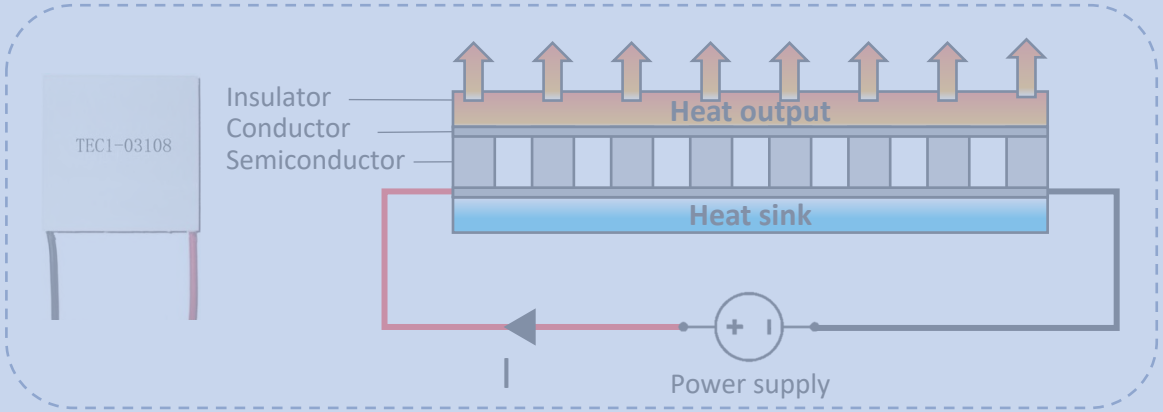
[6]

- ✓ Be



Objective: investigate the impact of thermal modality on neurofeedback performance

- ✓ Convenient: Peltier cells
  - Affordable & easy to use



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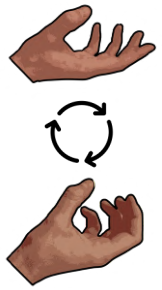
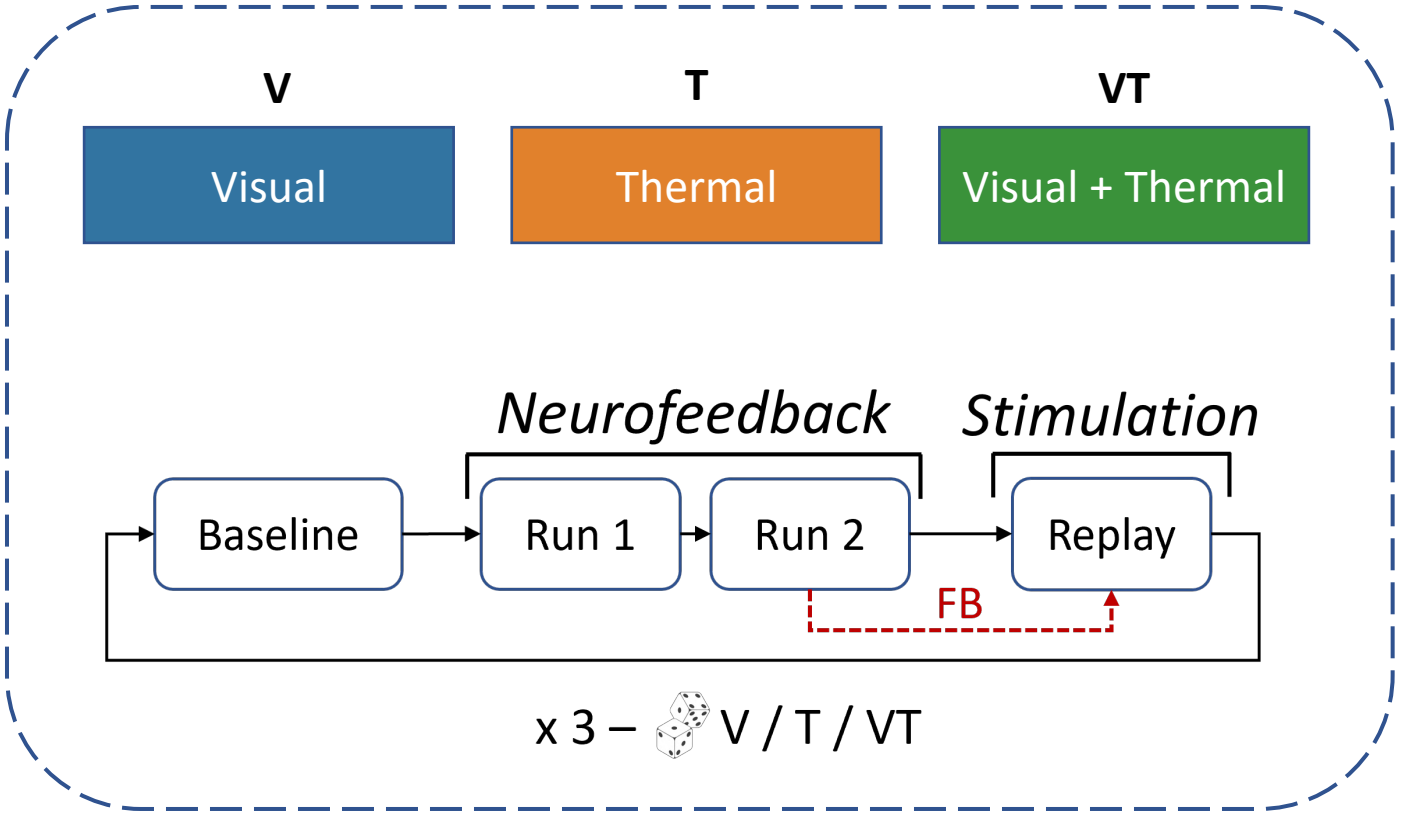
Materials and Methods

Mental task

Kinesthetic **M**otor **I**magery (KMI)





24 participants – 31 EEG electrodes

Neurofeedback runs

1 run: 20 trials

1 trial: 5 s rest, 10 s task

FB: online ERD

Laplacian on C3

[8 Hz - 20 Hz]

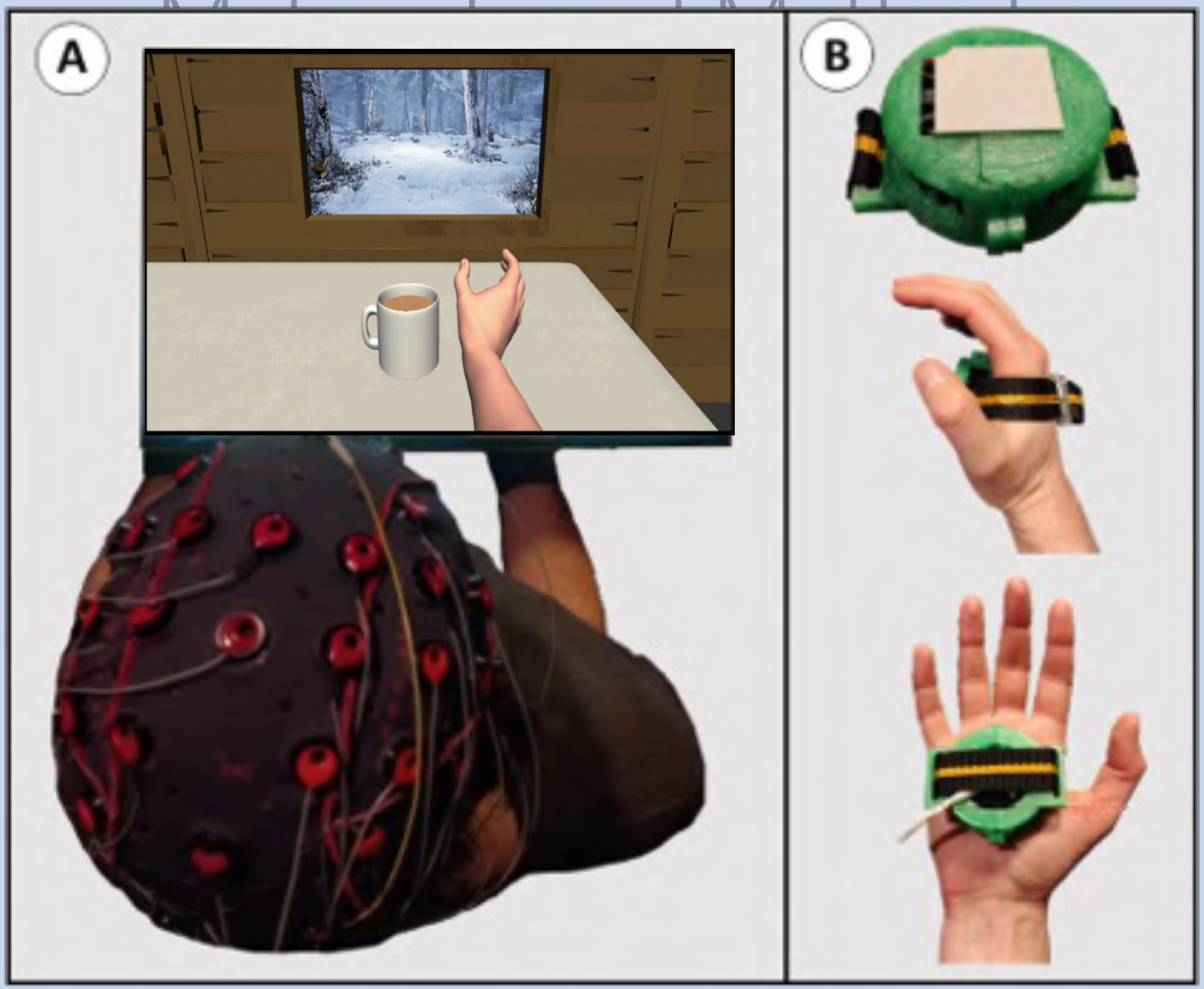
Stimulation run

No KMI

Stimulation only (replay of feedback generated during 2nd NFB run)

Mental task

Kinesthetic
Motor
Imagery (KMI)



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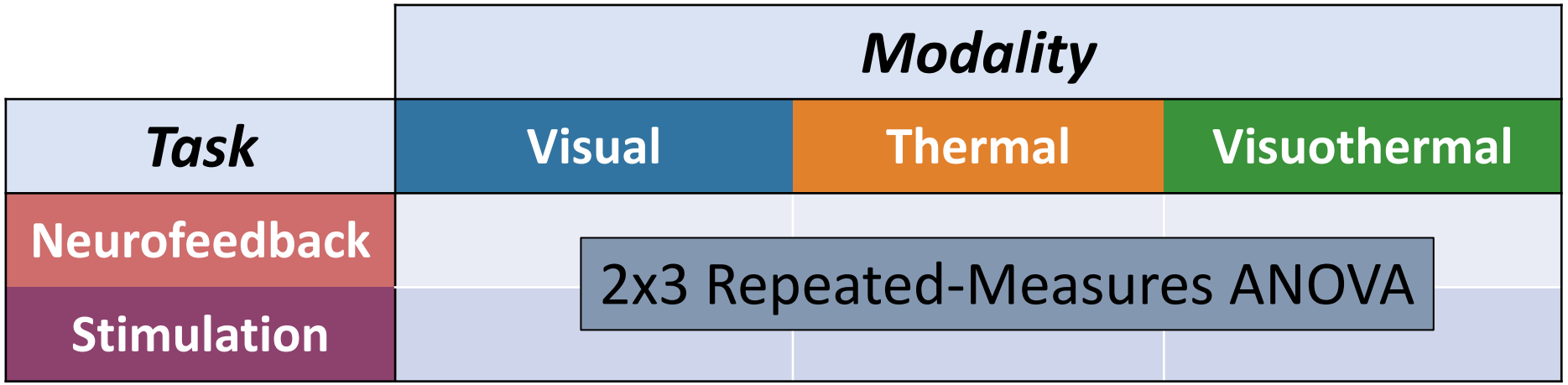
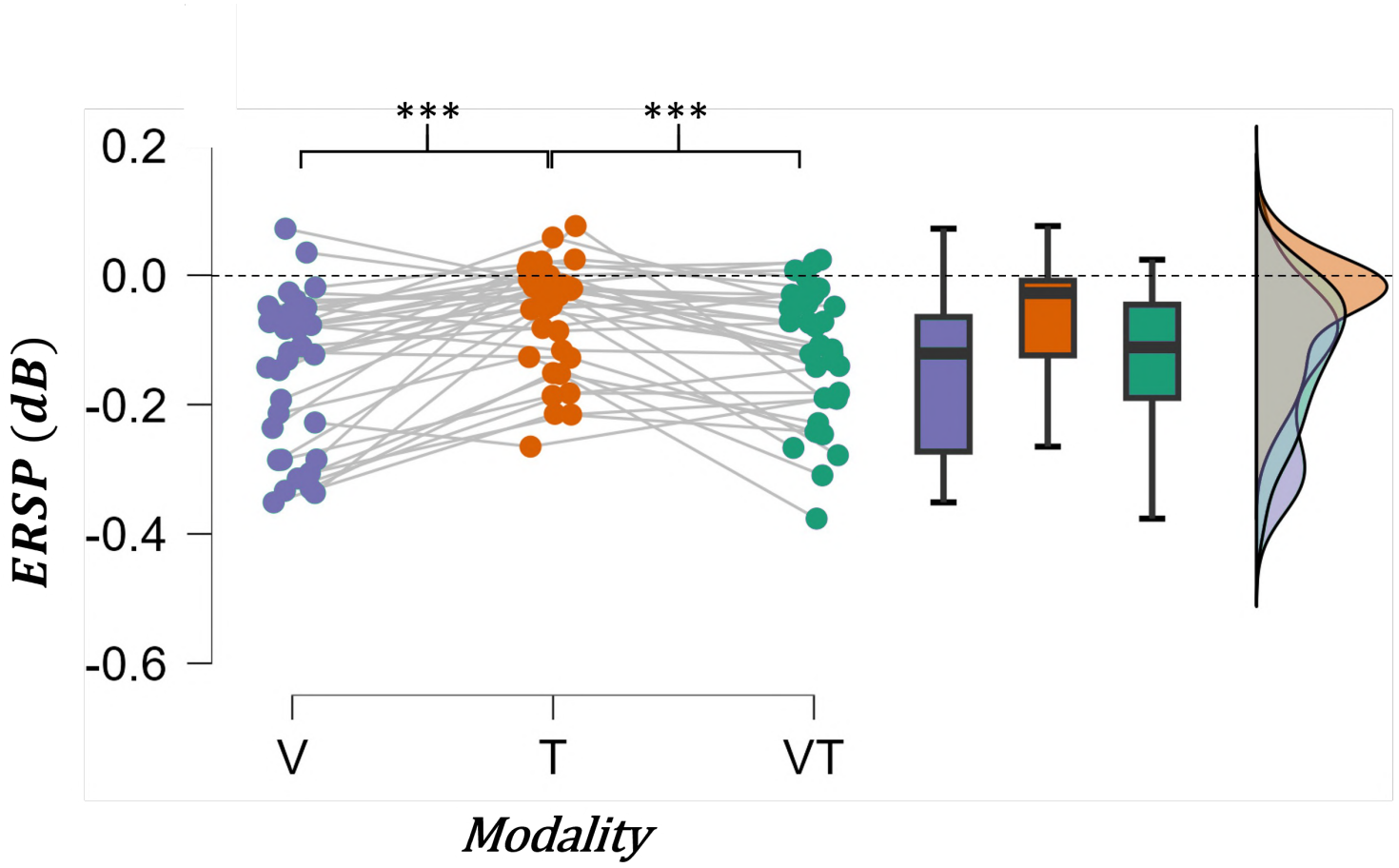
Materials and Methods



Variables

- ERD computed **on**line: $\underline{ERD_{on}}$ → only ER**D** (ERS set to 0)
  - → **Feedback**
- ERSP computed **off**line: $ERSP$ → includes **both** ERD & ERS

Results on *ERSP* 1/3: main effect of *Modality*



Better performance with V and VT feedback compared to T

☞ ≠ intuitiveness

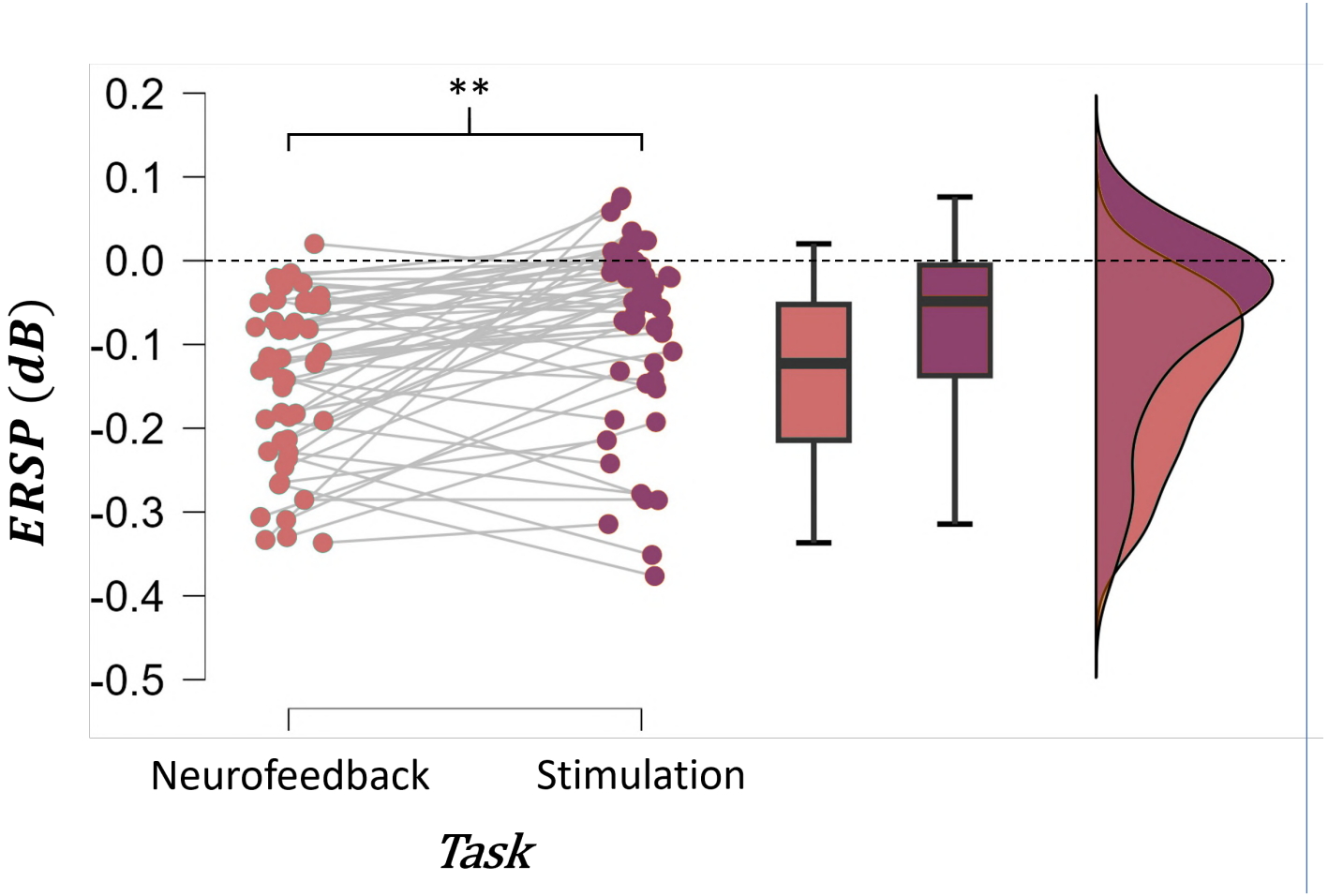
☞ ≠ stimulation delay

➡ **Richer information in V** (vs T)

Similar performance between V and VT feedback

☞ Possible to combine T modality to V without impairing V performance

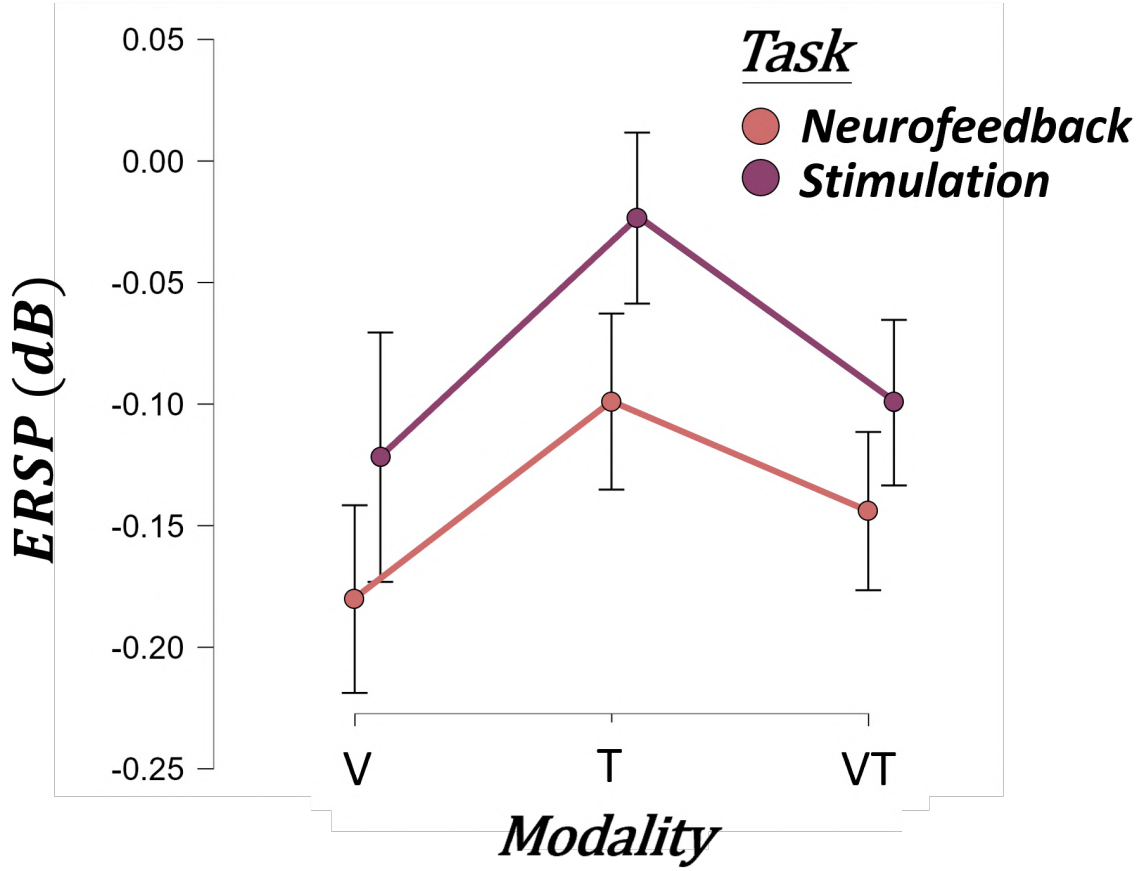
Results on *ERSP* 2/3: main effect of *Task*



☞ **Neurofeedback** brings about **greater desynchronization than Stimulation**.

☞ **Stimulation** can **generate ERDs on its own**.

Results on *ERSP* 3/3: no interaction



⚠ No interaction. For information only.

- ☞ Similar effect of ***Modality*** on ERSP for **Neurofeedback** and **Stimulation**
- ☞ It seems **visual Stimulation** (moving hand) **causes desynchronization on its own**.
- ☞ Probable presence of an **Action Observation** (AO) effect with **V** and **VT** modalities [11]

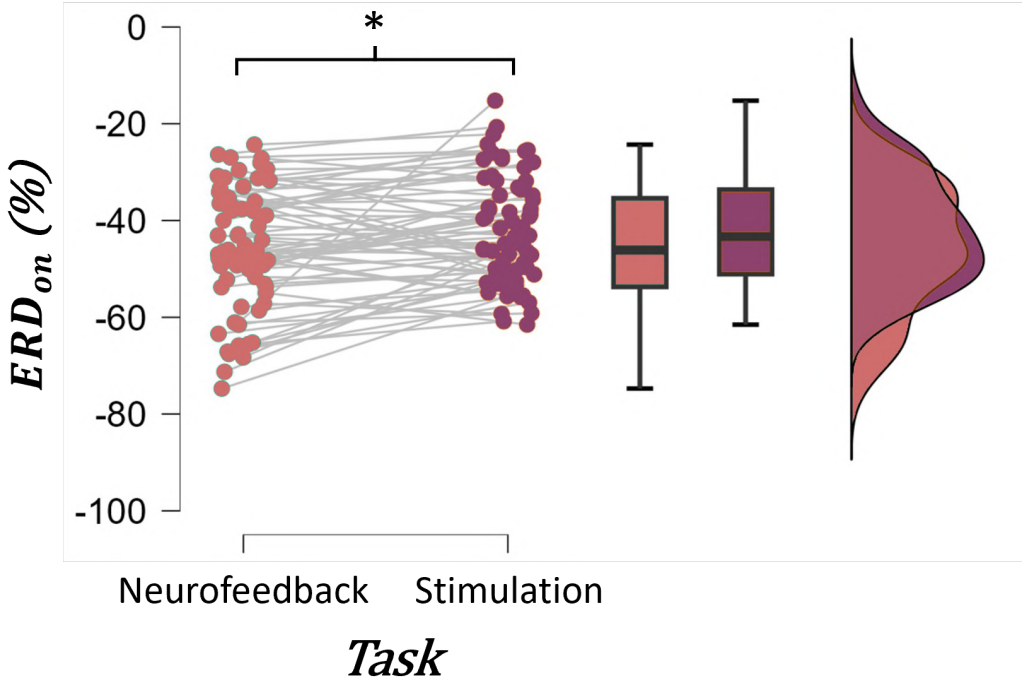
[11] Nagai & Tanaka (2019)

Results on ERD_{on}

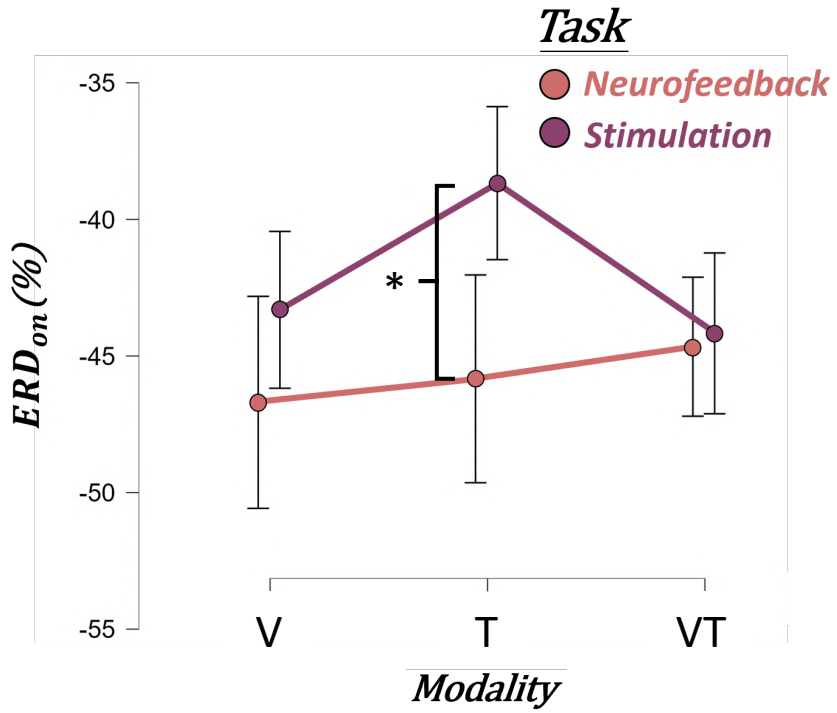
No main effect of ***Modality*** on ERD_{on}

☞ Probably due to setting ERS to 0 during online processing.

Main effect of ***Task***



Modality * Task interaction



Take-home messages

- ☞ Computing feedback only based on ER**D** might **not** be **an ideal practice**. Information loss, variable less reliable. No training of **ERS minimization**.

- ☞ From ***ERSP*** investigation, it seems **possible to combine** **Thermal** modality to **Visual** modality (**VT**) without impairing performance of **Visual** modality.

- ☞ Probable **Action Observation** effect of the **Visual** feedback, **complementary** with KMI-induced ERDs.

- ☞ **Visuo-thermal** relevant for therapeutical applications. Combines **MI**-NFB, **AO** [11] (ERDs) and clinical benefits of **thermal stimulation** [9, 10].

[9] Chen, et al. (2005) [10] Wu, et al. (2010) [11] Nagai & Tanaka (2019)

Upcoming work and Perspective

Additional analyses:

☞ **Spatial** & **spectral** investigation of brain activity

☞ **Neural correlates** of modalities and tasks

Improving thermal modality:

☞ Use also **cold** temperatures (two directions) [12]

☞ Increase **intensity** & variation **speed** (easier detection) [12]

Perspective:

☞ **Clinically test VT** neurofeedback as therapeutical application.

[12] Wilson et al. (2012)

Thank you for your attention !

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GRASP-IT

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