

Unexpected Perturbation of Immediate and Final Action Goals during Grasp Planning

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INTRODUCTION

-- When the prepared movement is not suitable for the current situations, motor re-planning is needed.

-- Motor re-planning involves two distinguished processes: the **inhibition of prepared actions** and the **implementation of a new motor plan**.

Inhibition

- ERPs: N2, P3;
- Neuroimaging: pre-SMA, ACC, PMv, rIFG ...

Implementation

- ERPs: P3, parietal slow waves;
- Source estimation: aIPS.

Motor
Re-planning

-- Previous studies found individuals re-planned their movements to adapt to unexpected changes in the target object (size, orientation, etc.), or changes in action goals.

-- For manual actions, action goals are not restricted to reaching and grasping the object (**immediate goal**), but also essential for a later, subsequent goal (**final goal**).

-- The role of immediate and final action goals in motor re-planning is still unknown.

HYPOTHESIS

- Perturbations on action goals engage more cognitive efforts to re-plan the movement.
- Motor re-planning under the perturbation in initial goals is more demanding than final goals, at least during the implementation of a new plan.

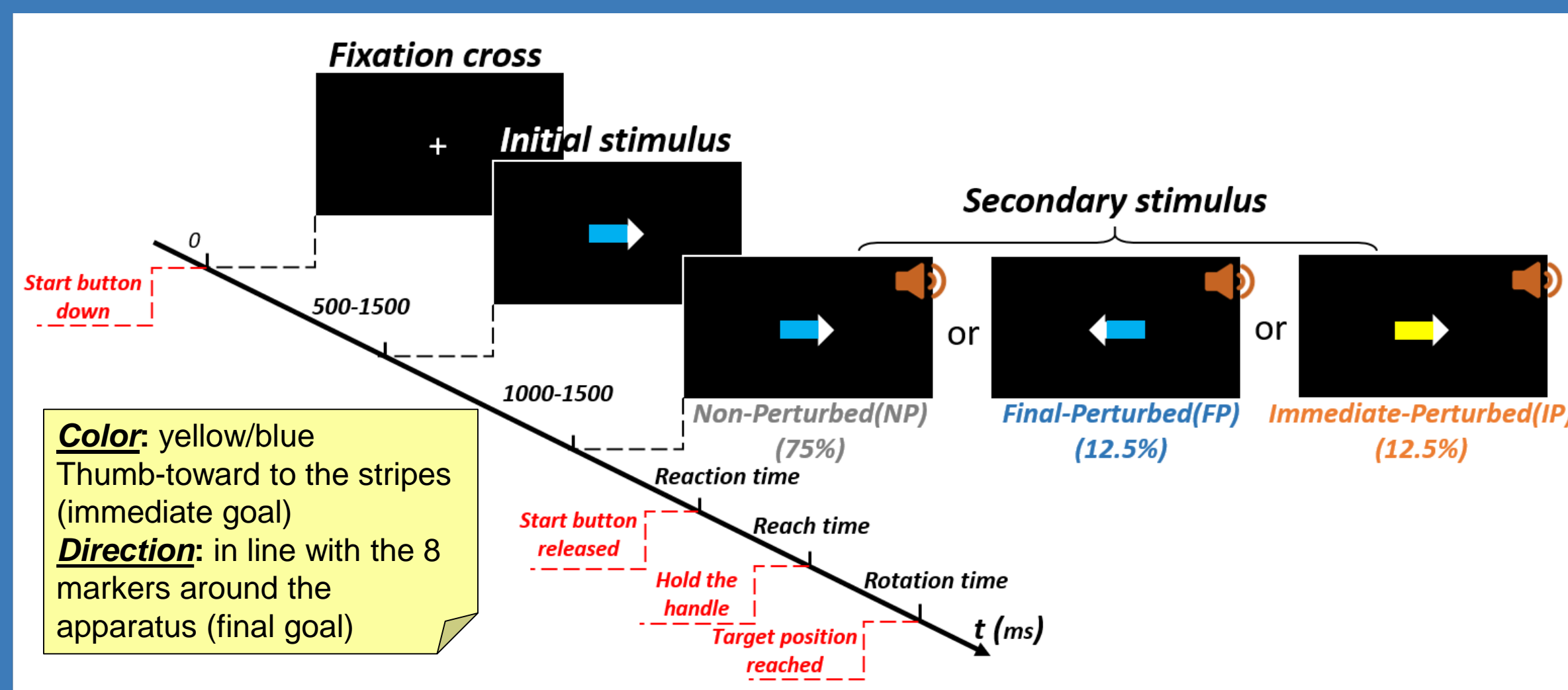
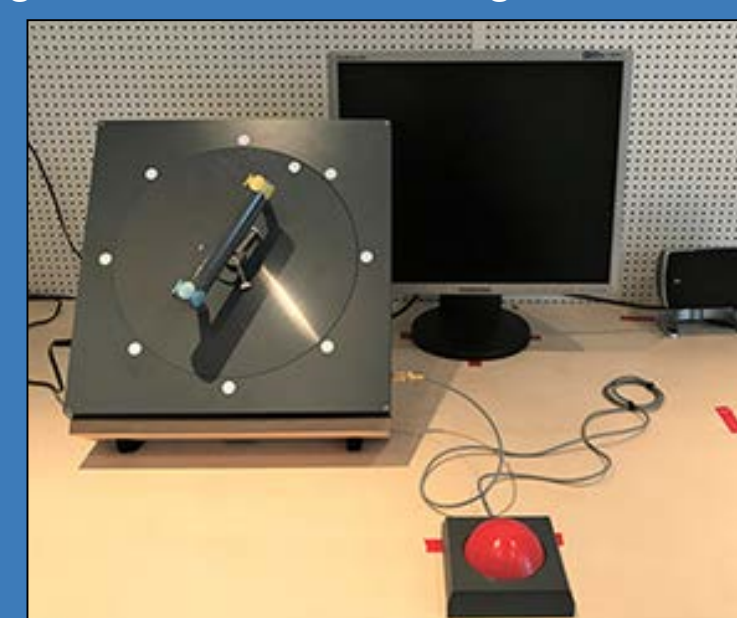
METHODS

Participants: 26 right-handed volunteers ($M_{age} = 25.08$, $SD_{age} = 3.60$)

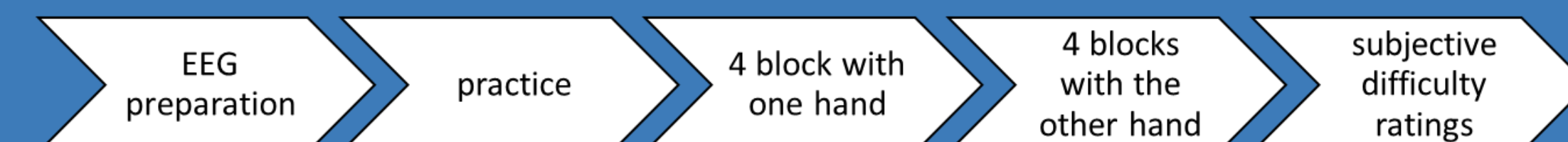
Task and design:

Grasp-to-rotate tasks with specified immediate (how to grip the handle) and final (where is the target position of the rotation) action goals. (90° rotation)

A modified “S1-S2” paradigm were used to present the action goals. In some trials, immediate or final goal got changed together with the imperative signal (tune).



Procedure:



Each block contains 48 trials. Starting hand was counterbalanced.

Data recording and analysis:

- Reaction, reach, and rotation times were recorded by Presentation.
- EEG signals were acquired by a 64-channel ANT system.
- Sampling rate = 512 Hz, band-filtered = 0.01- 30 Hz
- Epoch: -100 - 700 ms (time-locked to the imperative signal)
- ERP peak amplitude: P2 (150 - 200), N2 (200 - 250), P3(250 - 500) in midline electrodes Fz / FCz / Cz / CPz / Pz.
- ERP slow waves (500 - 600, 600 - 700) over 9 ROIs (AL, AM, AR, CL, CM, CR, PL, PM, PR)

RESULTS

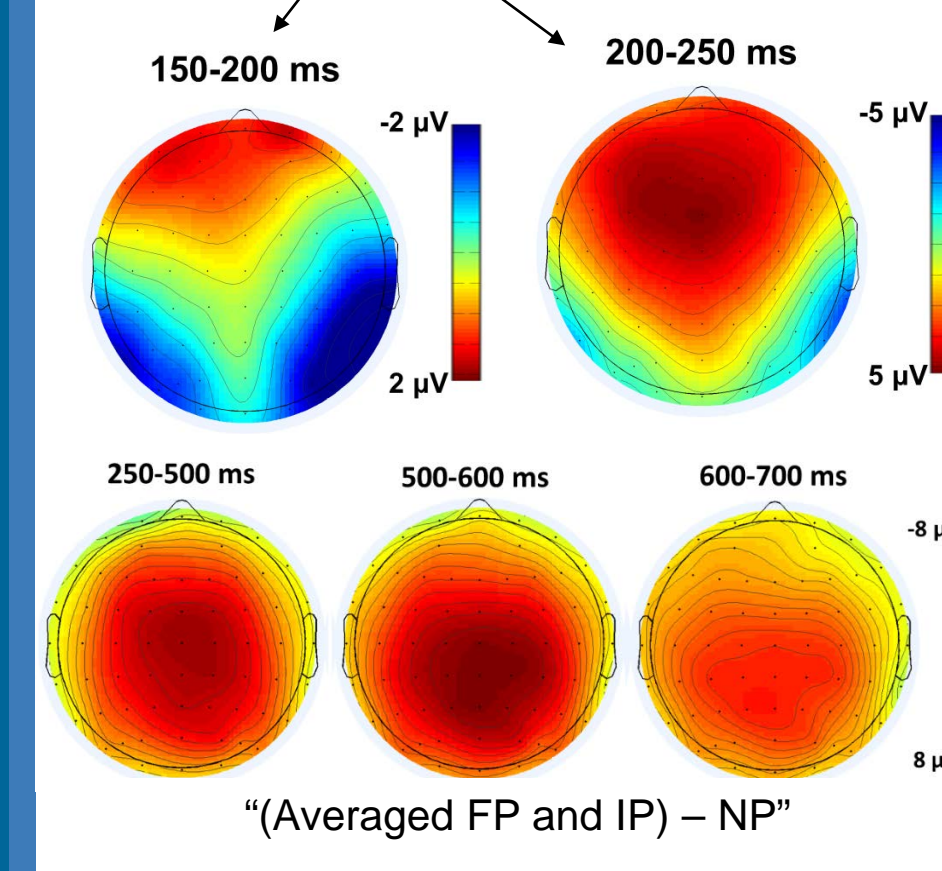
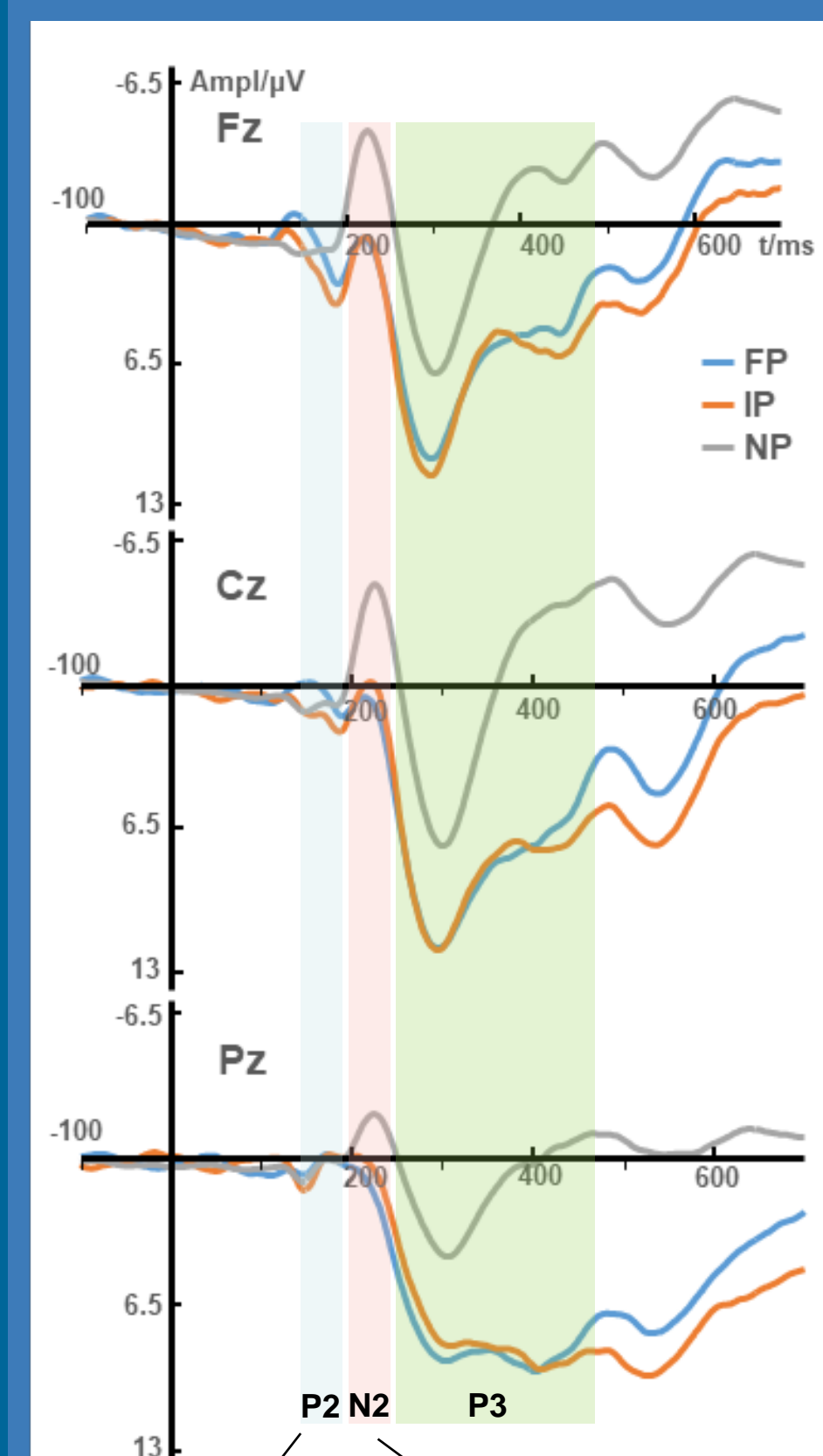
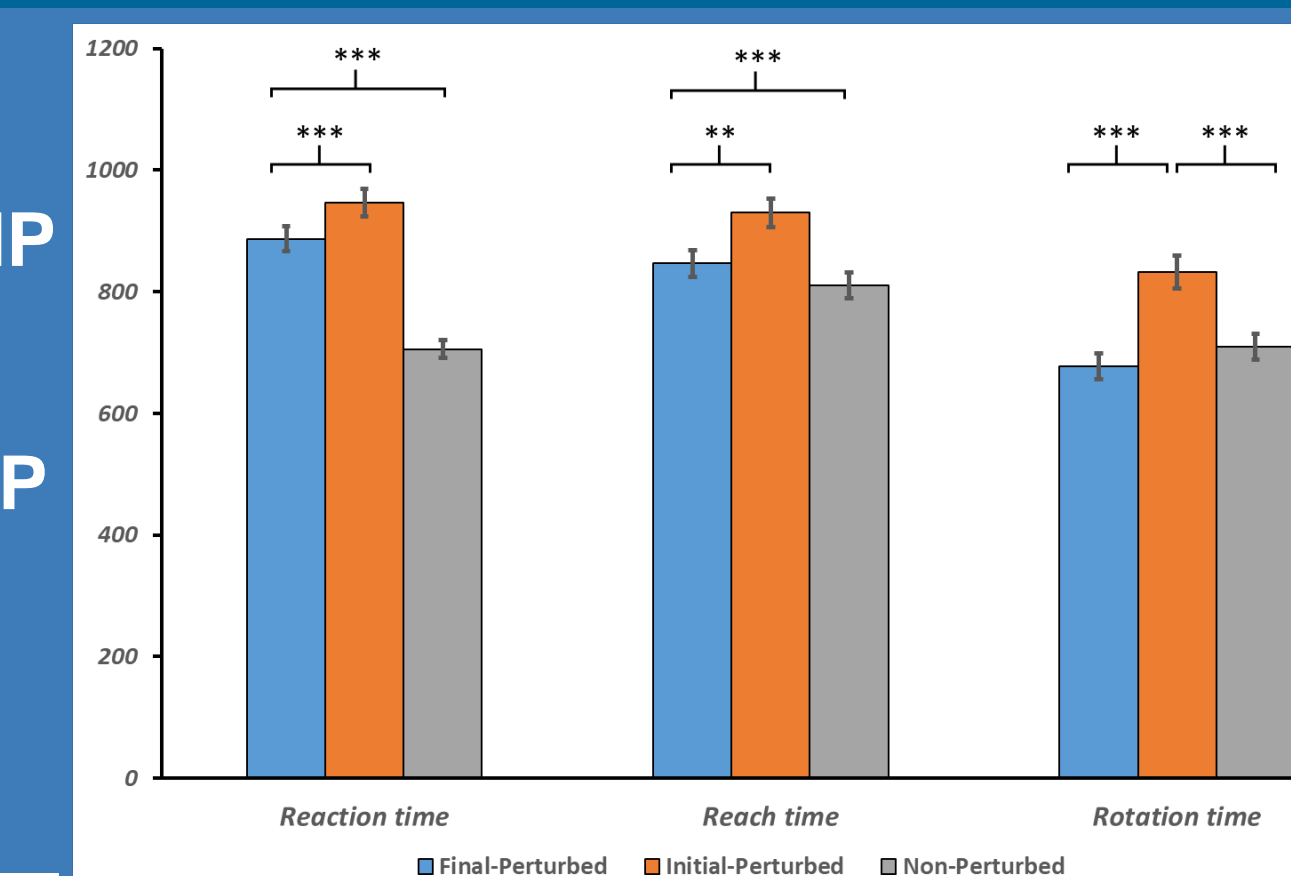
Behavioral results:

Reaction time: $IP > FP > NP$

Reach time: $IP > FP > NP$

Rotation time: $IP > NP = FP$

Difficulty rating: $IP > FP$



Electrophysiological results:

-- P2 (150 – 200 ms)

FP = IP > NP (at Fz, FCz, and Cz)

-- N2 (200 – 250 ms)

NP > FP = IP (at all electrodes)

-- P3 (250 – 500 ms)

FP = IP > NP (at all electrodes)

-- Slow waves (500 – 600 ms)

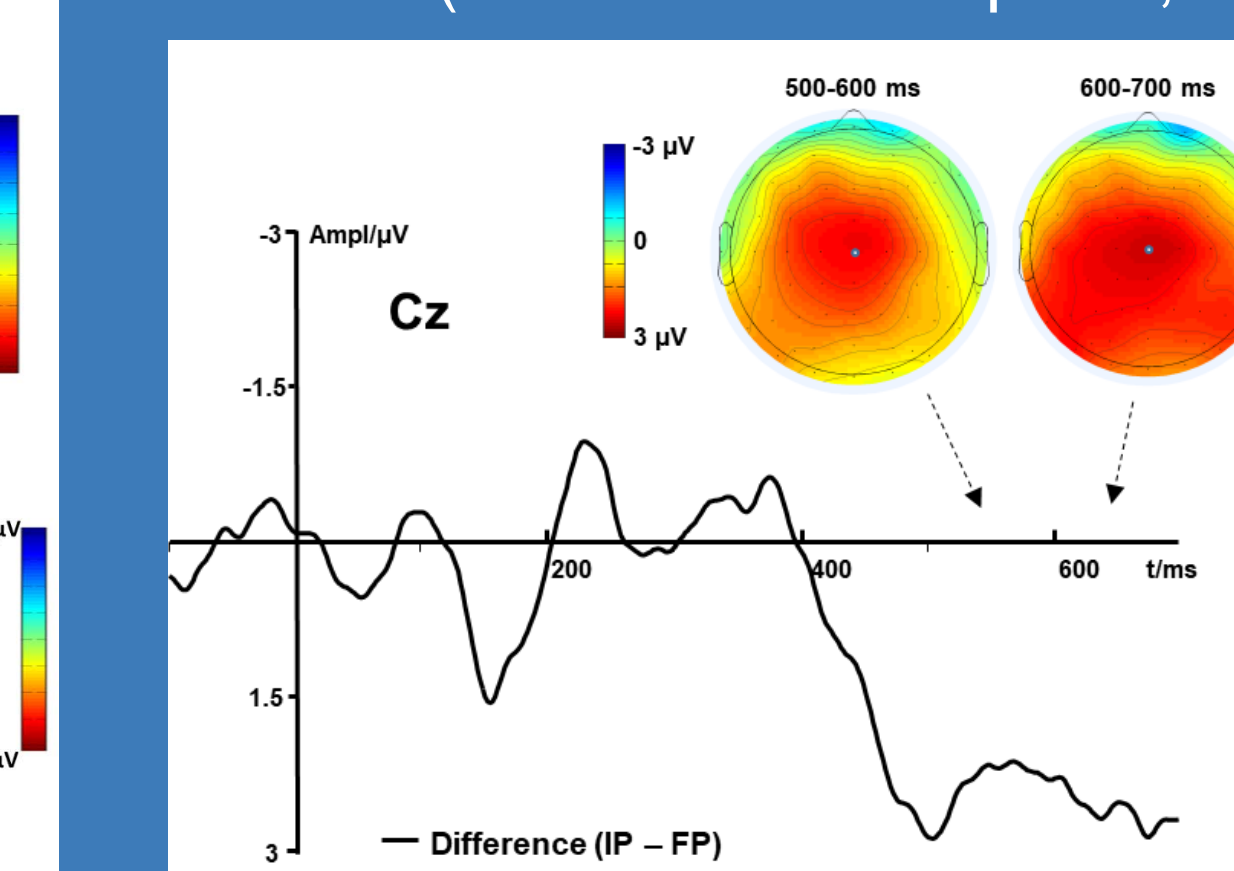
FP > NP, IP > NP (at all ROIs)

IP > FP (at AM, CL, CM, PL, and PM)

-- Slow waves (600 – 700 ms)

FP > NP, IP > NP (at all ROIs)

IP > FP (at all ROIs except AL,AR)



DISCUSSION

• Perturbed (FP & IP) vs. Non-Perturbed (NP)

- Perturbations on immediate or final action goals led to motor re-planning, which required more efforts (prolonged reaction time, enlarged anterior P2, P3, and slow waves).
- Enlarged N2 for NP could be attributed to the monitoring of the movement plan (“double-check” movements before releasing the start button), whereas the N2s for FP and IP might be overlapped by the increasing P3.

• Final-Perturbed (FP) vs. Immediate-Perturbed (IP)

- Re-planning the movement to adapt to the perturbations in immediate action goals required more efforts than on final action goals (prolonged reaction time and reach time, as well as more positive centro-parietal slow waves).
- No difference for P2, N2 and P3 amplitude might reflect that **the increased cognitive efforts (for IP) are employed for the implementation of new motor plan rather than the inhibition of the prepared actions**, which is similar to the hysteresis phenomenon in sequential or repetitive movement tasks.

CONCLUSIONS

- More cognitive efforts are needed for re-planning the manual actions to adapt to changes on action goals.
- A perturbed immediate goal is more demanding than a perturbed final goal in re-planning manual actions, and the increased demands are employed for generating a new motor plan rather than inhibiting the prepared actions.

ACKNOWLEDGMENTS

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