Neural correlates of the relation between body ownership and agency: a tDCS study

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INTRODUCTION

Voluntary actions are accompanied by the experience of controlling the own movements (sense of agency) and the feeling that the moving body part is belonging to the self (sense of body ownership). Agency and ownership have been mainly investigated separately, leaving unexplored the neural underpinnings of the relation between the two. **Aim.** The current study is aimed at investigating the causal role of the premotor cortex (PM) and the cerebellum, in modulating the relation between body ownership and agency.

METHOD

Participants

Experiment 1
PM
20 healthy participants
11 F, age: 22.60 ± 3.30

Experiment 2
Cerebellum
25 healthy participants
9 F, age: 22.04 ± 3.38

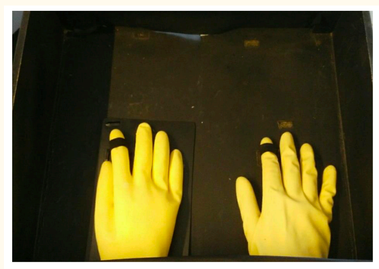
tDCS

Anodal and Sham tDCS
before RHI induction

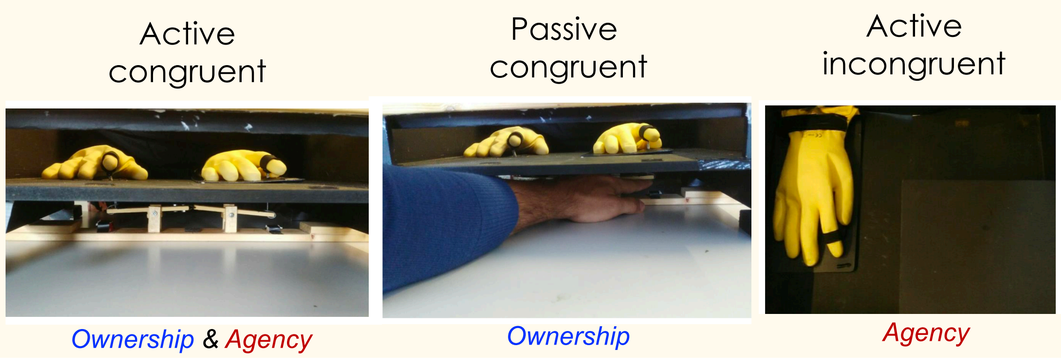
Experiment 1		Experiment 2	
Anode	Cathode	Anode	Cathode
Left PM (FC5)	Right supraorbital area	Right Cerebellum	Right buccinator muscle

Moving Rubber Hand Illusion

Experimental set up



Conditions



Measures

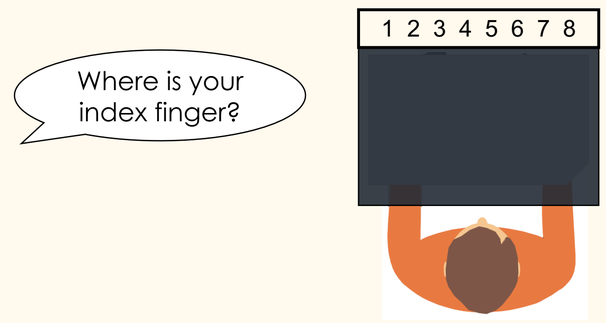
mRHI Questionnaire

Ownership-statements
- I felt as if I was looking at my own hand
- I felt as if the rubber hand were my hand

Agency-statements
- The rubber hand moved just like I wanted it to, as if it was obeying at my will
- I felt as if I was causing the movements of the rubber hand

Totally disagree — Totally agree

Proprioceptive drift



RESULTS

The mRHI paradigm in the sham tDCS session

The expected pattern of mRHI results was found
in both Experiments

Questionnaire
Comparisons between ownership- and agency- statements with the respective control statements showed that:

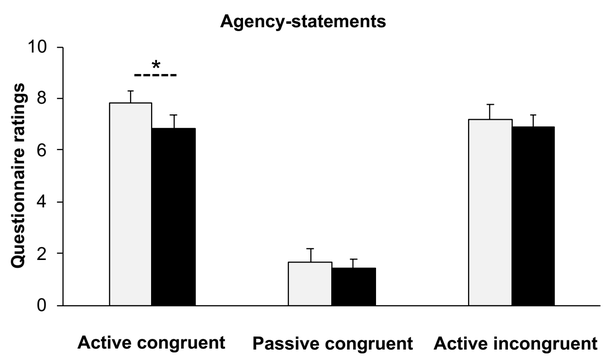
a) Ownership and agency were elicited in the active congruent condition
b) Ownership but not agency was evoked in the passive congruent condition;
c) Agency but not ownership was elicited in the active incongruent but not in the active incongruent conditions.

Proprioceptive drift
Was significantly different from 0 (where 0 means no drift) in the active congruent and in the passive congruent condition.

Anodal tDCS-related changes in the mRHI pattern of results

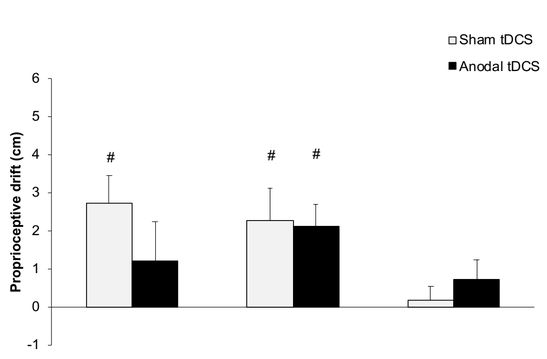
Questionnaire

Experiment 1
PM

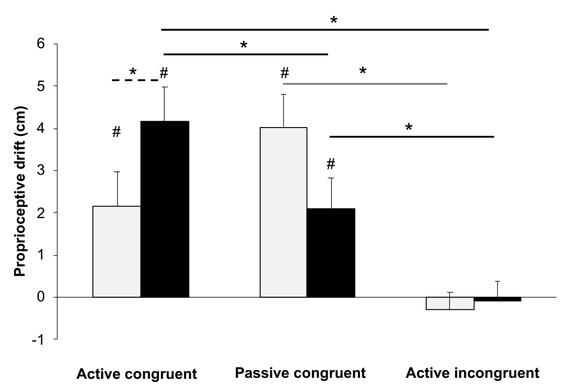


Proprioceptive drift

Experiment 1
PM



Experiment 2
Cerebellum



differences from 0
--- difference between tDCS sessions
— differences across conditions

Subjective feeling of agency
- *decreased* after anodal tDCS over PM
- not affected by anodal tDCS over the Cerebellum

Proprioceptive drift:
- *abolished* after anodal tDCS over PM
- *enhanced* after anodal tDCS over the Cerebellum

These effects **were selective for the active congruent condition** in which agency and ownership are usually evoked in conjunction

DISCUSSION

By combining the mRHI with different types of tDCS we were able to demonstrate that PM and Cerebellum differently contribute to proprioceptive and subjective components of ownership and agency during voluntary actions. More precisely, facilitating the activity of PM or the cerebellum had different modulatory effects on proprioceptive recalibration of the participants' hand toward the rubber hand, with the former (i.e., PM) preventing and the latter (i.e., cerebellum) increasing the proprioceptive drift.

REFERENCES

Tsakiris M, Longo MR, Haggard P. Having a body versus moving your body: neural signatures of agency and body-ownership. Neuropsychologia 2010; 48: 2740.
Kalckert A, Ehrsson HH. Moving a rubber hand that feels like your own: a dissociation of ownership and agency. Front hum neurosci 2012; 6:1.

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