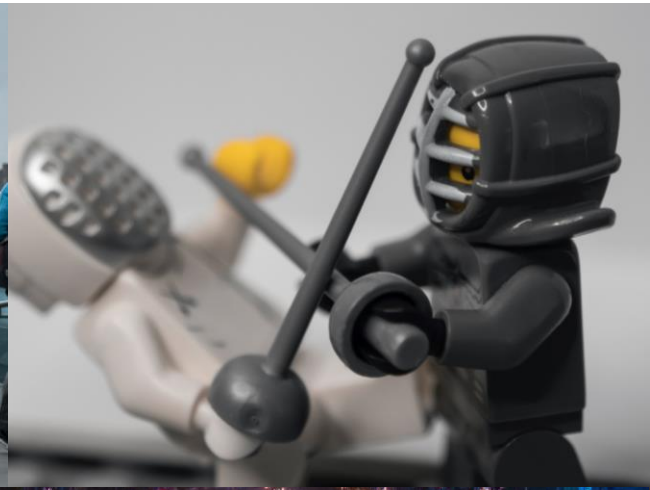
Boosting social prediction abilities with cerebellar stimulation: evidence from tDCS studies in healthy adults and in patients with cerebellar malformation

Alessandra Finisguerra

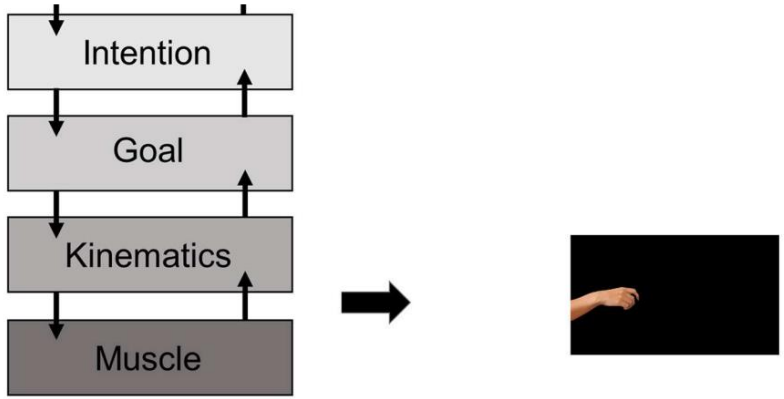
IRCCS EUGENIO MEDEA
ASSOCIAZIONE la Nostra Famiglia

The importance of predicting others' behaviour



«High level» contribution to action prediction

We can infer the intention behind others' behaviours on yhr nand we read the observed movement also on the basis of previous experience and from the context in which actions are executed (Kilner 2007; Amoruso and Urgesi, 2016; Amoruso et al., 2016,2018, 2020; Bianco et al., 2020; Betti, 2021)



From Amoruso & Finisguerra (2019).

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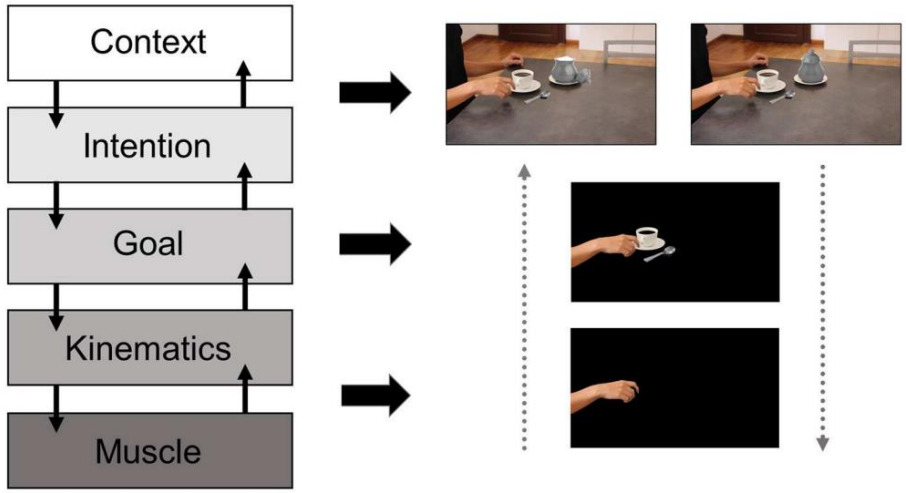

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«High level» contribution to action prediction

How does the cerebellum contribute to context-embedded prediction in social scenarios?

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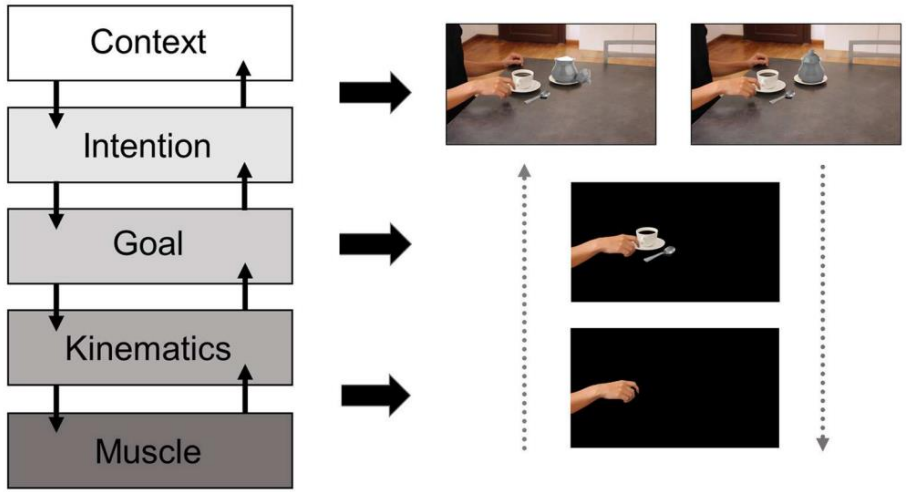

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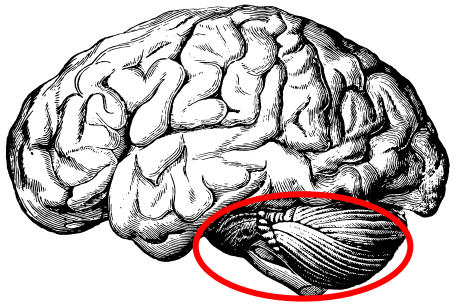
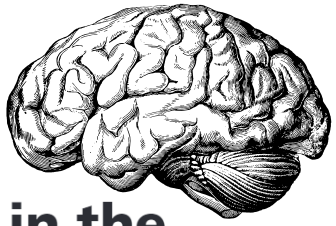


How does the cerebellum contribute to context-embedded prediction in social and non social scenarios?



Internal models in the cerebellum

Daniel M. Wolpert, R. Chris Miall and Mitsuo Kawato

The cerebellum as a neuronal prediction machine

Go to:

More than simply a neuronal learning machine, the brain is a prediction machine. Across sensory and motor systems, growing evidence suggests that a key operating principle of the brain is to establish internally generated predictions that can be compared against feedback from the external world in order to guide anticipatory actions and perceptions (Keller and Mrsic-Flogel, 2018).

The cerebellum has long been thought to operate predictively to support motor control and motor learning (Wolpert et al., 1998). As originally proposed by Masao Ito, the cerebellum is hypothesized to utilize a predictive model that anticipates the expected outcome of motor commands in order to refine future movements (Ito, 1970; Ito, 1972). Indeed, decades of research have provided considerable support for this hypothesis (Ohyama et al., 2003), and revealed many of the circuit pathways (Apps and Garwicz, 2005) and mechanisms (Carey, 2011) that allow the cerebellum to predictively modify motor output. However, emerging evidence suggests that the role of the cerebellum in motor control may be more complex than previously appreciated (Medina, 2019). Moreover, it has also become clear that the cerebellum plays a much wider role in brain function than simply refining movements (Buckner, 2013; Leiner et al., 1986; Schmahmann, 1991; Sokolov et al., 2017; Strick et al., 2009). Recently, with advances in modern circuit

From Hull (2020). Prediction signals in the cerebellum: Beyond supervised motor learning. *ELife*

The Cerebellum (2020) 19:102–125
https://doi.org/10.1007/s12311-019-01068-8

REVIEW

The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper

Georgios P. D. Argyropoulos[1] · Kim van Dun[2] · Michael Adamaszek[3] · Maria Leggio[4,5] · Mario Manto[6,7] · Marcella Masciullo[8] · Marco Molinari[9] · Catherine J. Stoodley[10] · Frank Van Overwalle[11] · Richard B. Ivry[12] · Jeremy D. Schmahmann[13]

https://doi.org/10.1007/s12311-020-01155-1

CONSENSUS PAPER

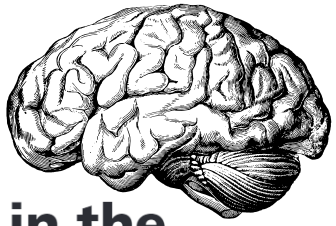
Consensus Paper: Cerebellum and Social Cognition

Frank Van Overwalle[1] · Mario Manto[2,3] · Zaira Cattaneo[4,5] · Silvia Clausi[6,7] · Chiara Ferrari[8] · John D. E. Gabrieli[9] · Xavier Guell[9,10] · Elien Heleven[1] · Michela Lupo[6] · Qianying Ma[1] · Marco Michelutti[11,12] · Giusy Olivito[6,7] · Min Pu[1] · Laura C. Rice[13] · Jeremy D. Schmahmann[10] · Libera Siciliano[14] · Arseny A. Sokolov[11,15,16,17] · Catherine J. Stoodley[13] · Kim van Dun[18] · Larry Vandervert[19] · Maria Leggio[6,7]

Abstract

The traditional view on the cerebellum is that it controls motor behavior. Although recent work has revealed that the cerebellum supports also nonmotor functions such as cognition and affect, only during the last 5 years it has become evident that the cerebellum also plays an important social role. This role is evident in social cognition based on interpreting goal-directed actions through the movements of individuals (social "mirroring") which is very close to its original role in motor learning, as well as in social understanding of other individuals' mental state, such as their intentions, beliefs, past behaviors, future aspirations, and personality traits (social "mentalizing"). Most of this mentalizing role is supported by the posterior cerebellum (e.g., Crus I and II). The most dominant hypothesis is that the cerebellum assists in learning and understanding social action sequences, and so facilitates social cognition by supporting optimal predictions about imminent or future social interaction and cooperation. This consensus paper brings together experts from different fields to discuss recent efforts in understanding the role of the cerebellum in social cognition, and the understanding of social behaviors and mental states by others, its effect on clinical impairments such as cerebellar ataxia and autism spectrum disorder, and how the cerebellum can become a potential target for noninvasive brain stimulation as a therapeutic intervention. We report on the most recent empirical findings and techniques for understanding and manipulating cerebellar circuits in humans. Cerebellar circuitry appears now as a key structure to elucidate social interactions.

How does the cerebellum contribute to context-embedded prediction in social and non social scenarios?



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Cortex
Available online 24 September 2021
In Press, Journal Pre-proof

Behavioural Neurology

Social prediction in pediatric patients with congenital, non-progressive malformations of the cerebellum: from deficits in predicting movements to rehabilitation in virtual reality

Urgesi, Butti et al., 2021

The Cerebellum (2020) 19:799–811
https://doi.org/10.1007/s12311-020-01168-w

ORIGINAL ARTICLE

Cerebellar Damage Affects Contextual Priors for Action Prediction in Patients with Childhood Brain Tumor

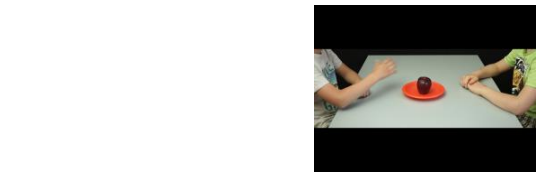
Butti, Corti et al., 2020

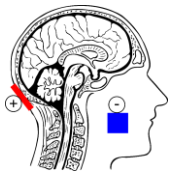
How does the cerebellum contribute to context-embedded prediction in social and non social scenarios?

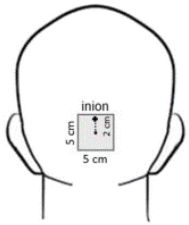
STUDY 1

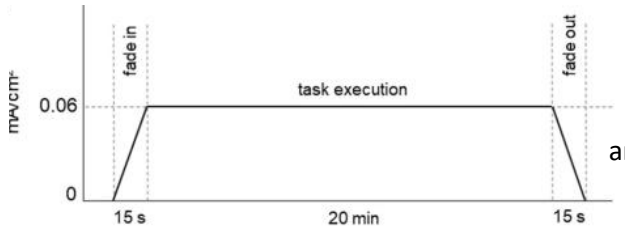
Study 1

ctDCS experiment in 24 healthy adults: procedure



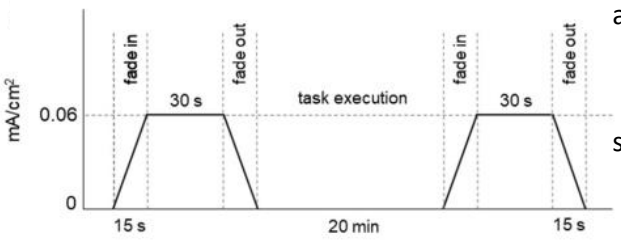






anodic/cathodic

and

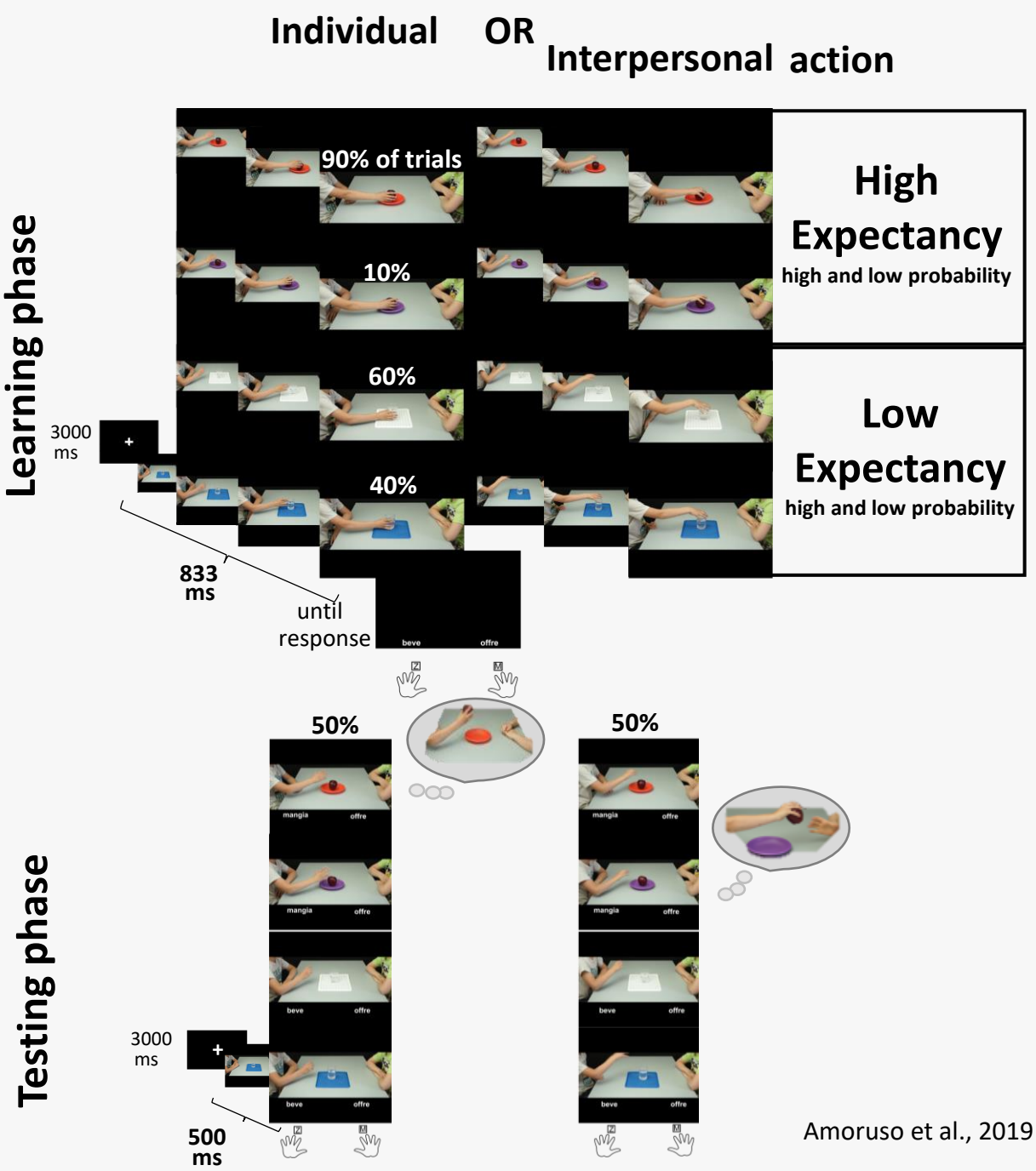


sham

time course

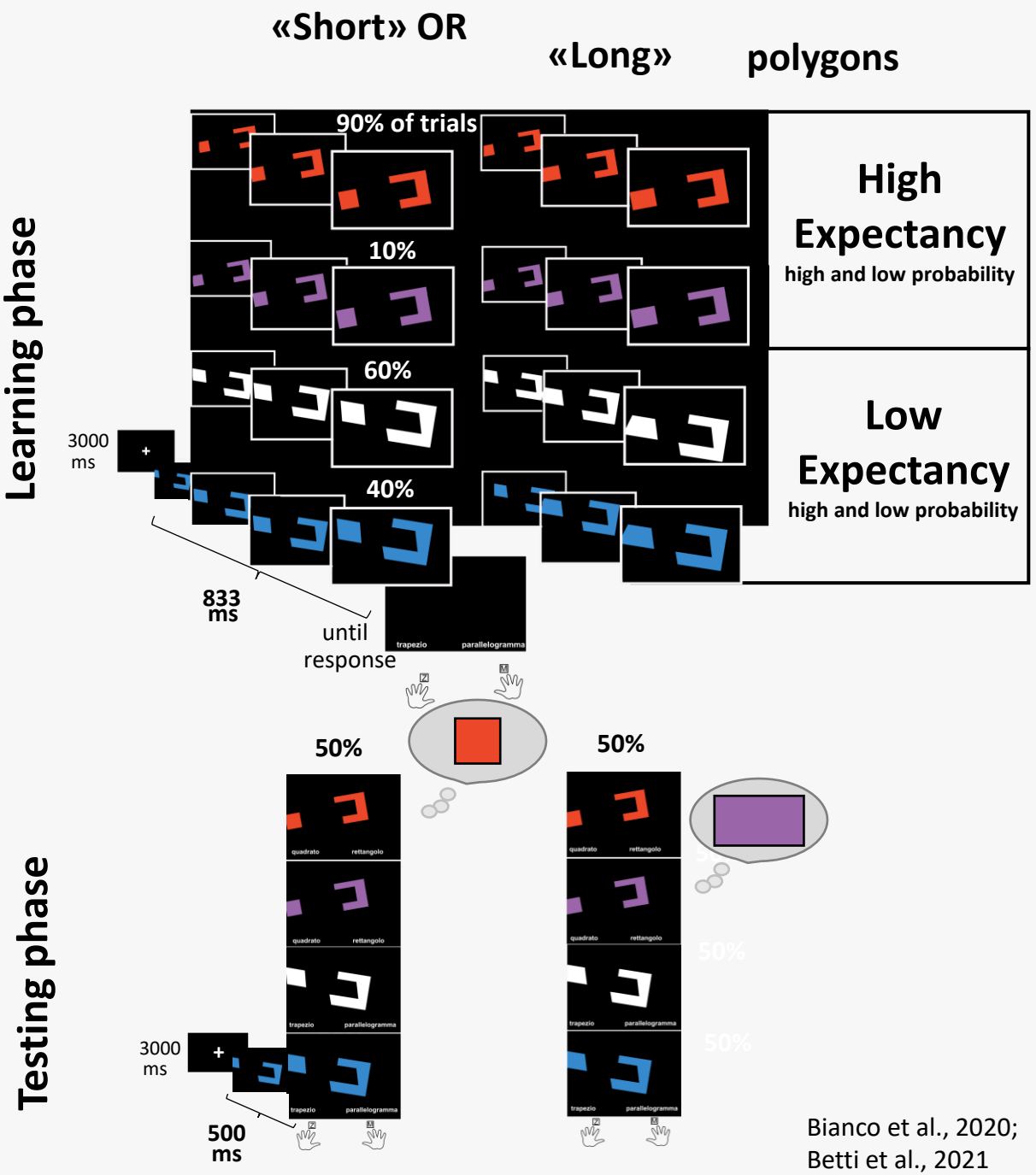
Oldrati et al., 2021

Action prediction task



Amoruso et al., 2019

Shape prediction task



Bianco et al., 2020;
Betti et al., 2021

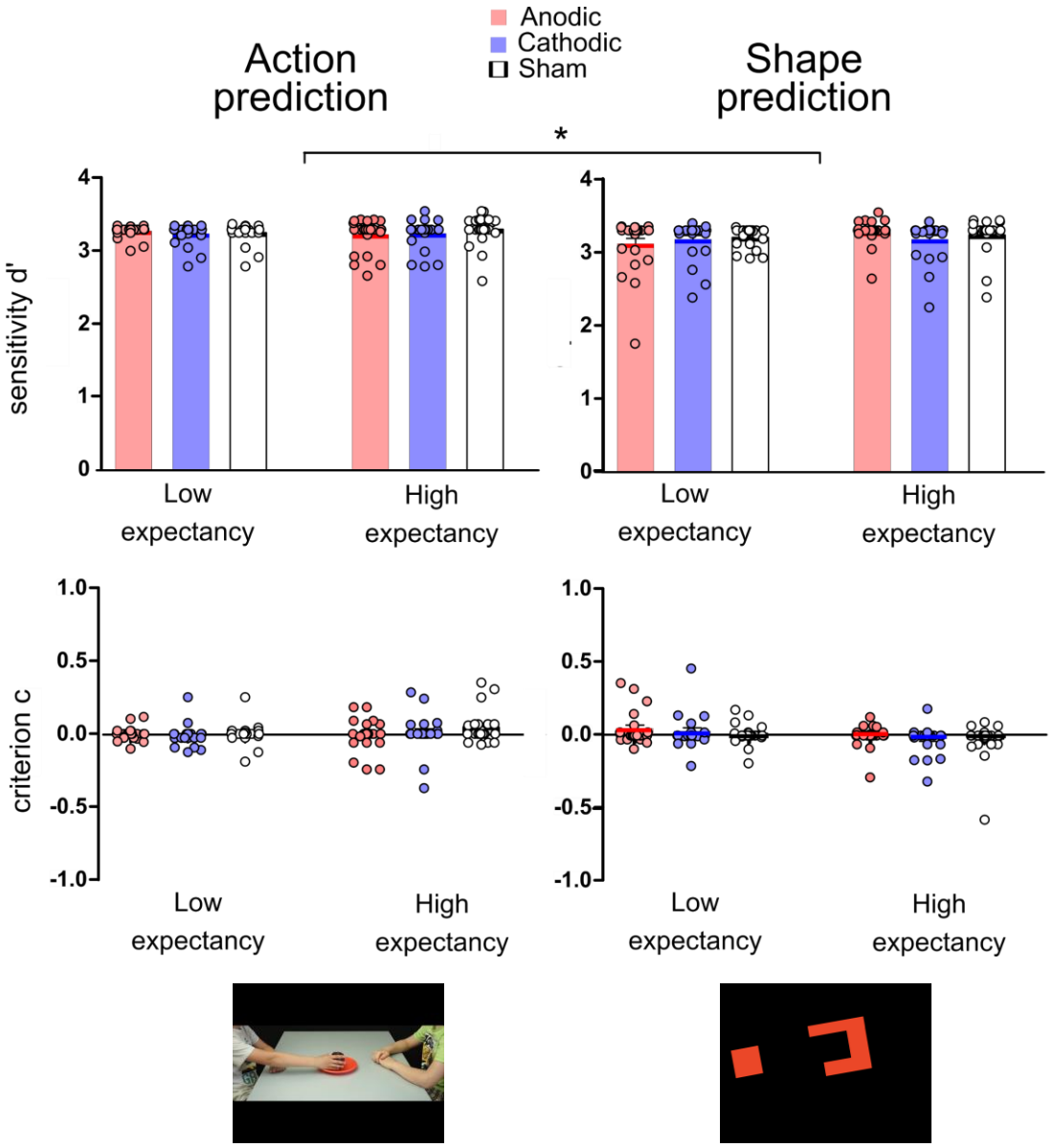
Study 1

ctDCS experiment in 24 healthy adults: Results learning phase

Oldrati et al., 2021

Does ctDCS affect recognition abilities either for social or non-social events?

Learning phase



ctDCS experiment in 24 healthy adults: Results testing phase

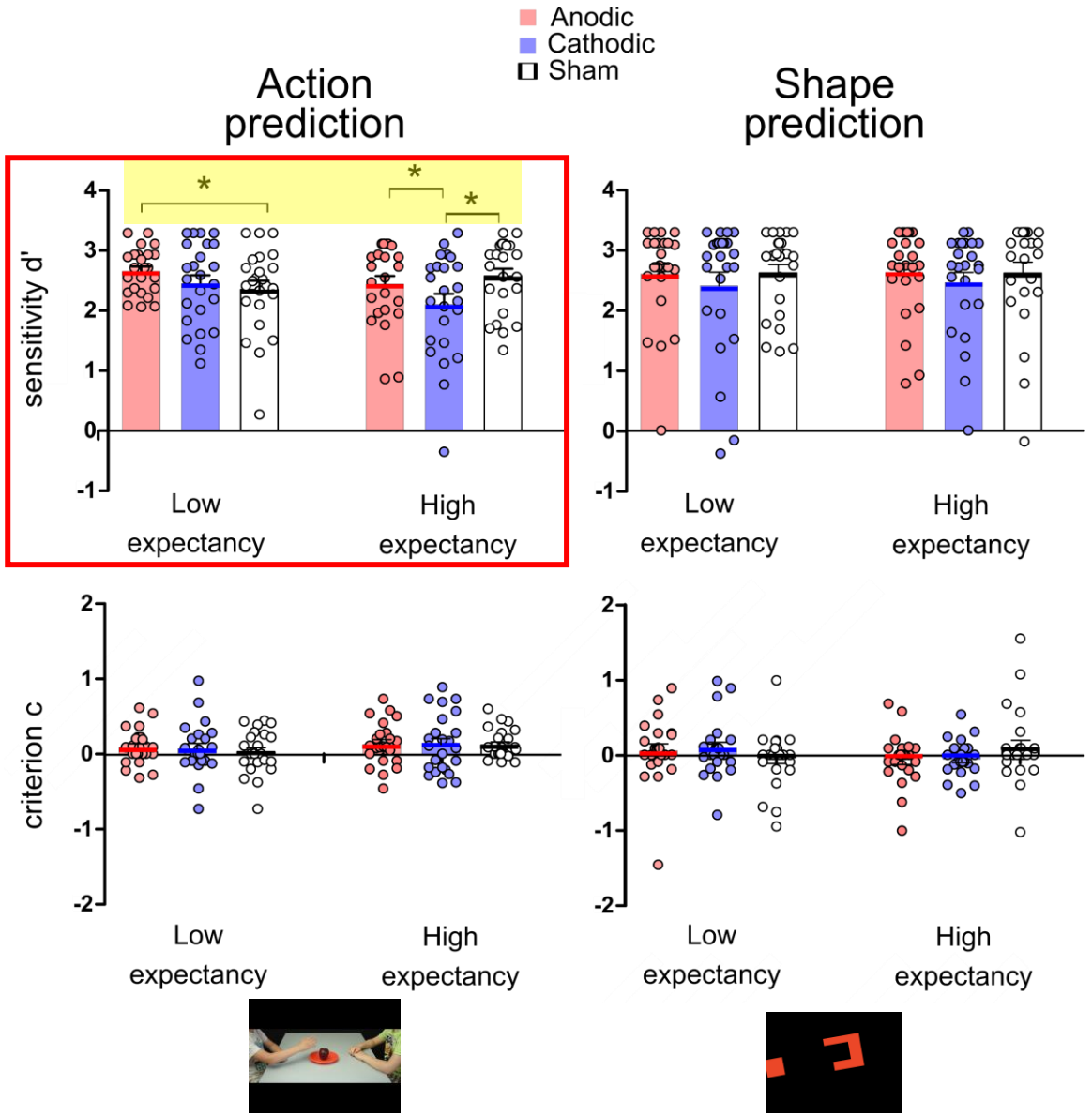
Task specific

Polarity dependent

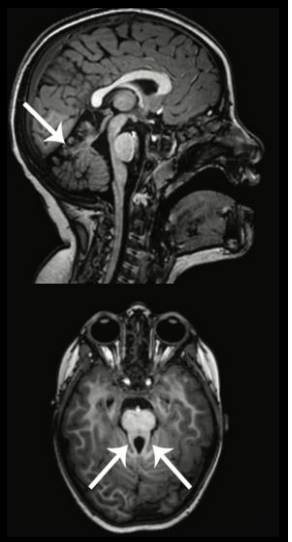
«Expectancy-dependent» effects

Oldrati et al., 2021

Does ctDCS affect prediction abilities either for social or non-social events? Testing phase



Can ctDCS boost social prediction abilities in cerebellar malformation?



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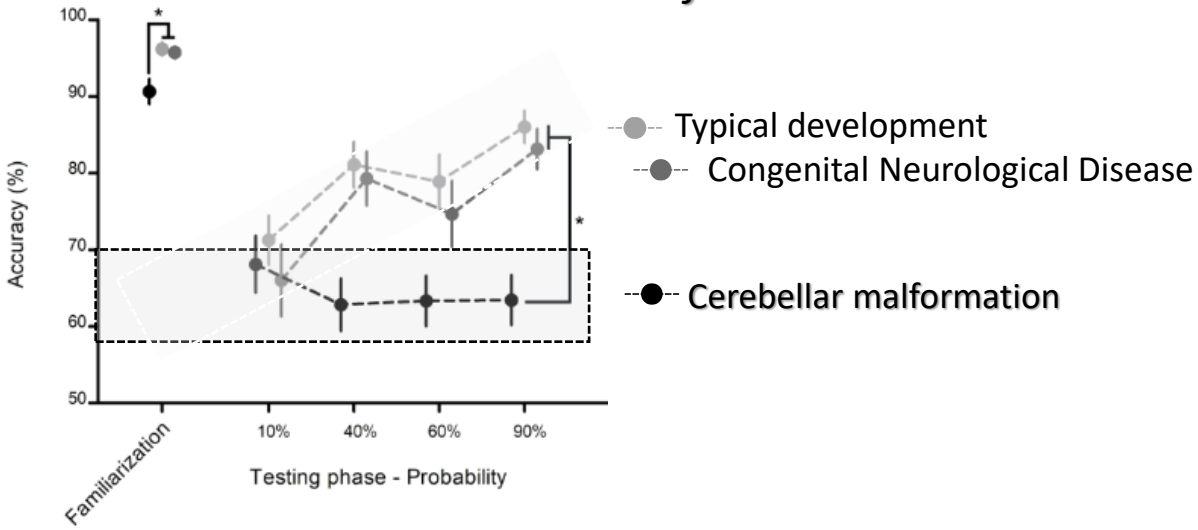
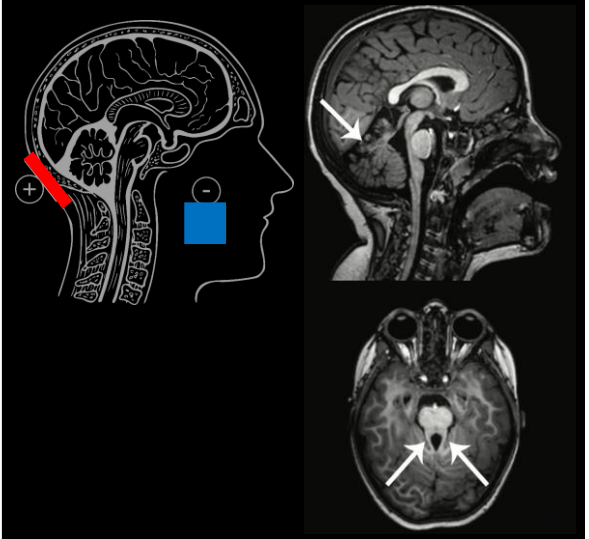
Urgesi, Butti et al., in press

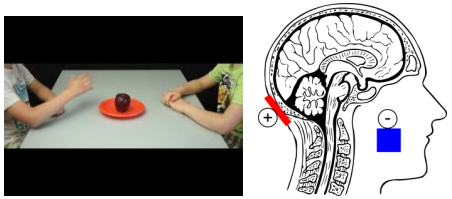
Contextual priors do not modulate action prediction in children and adolescents with cerebellar malformation

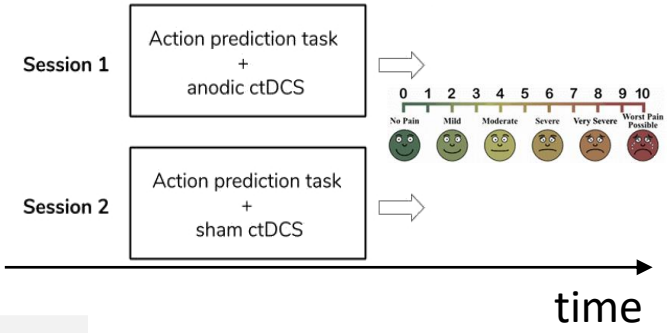


Can ctDCS boost social prediction abilities in cerebellar malformation?

STUDY 2







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2	Male	16	Cerebellar atrophy
3	Male	15	Hemispheres hypoplasia
4	Female	15	Rhomboencephalosynapsis
5	Male	27	Joubert syndrome
6	Male	15	Vermis hypoplasia
7	Male	11	Dandy Walker malformation
8	Male	17	Vermis hypoplasia
9	Male	19	Joubert syndrome
10	Male	19	Joubert syndrome
11	Female	17	Cerebellar atrophy

recruitment still ongoing

Can ctDCS boost social prediction abilities in cerebellar malformation?

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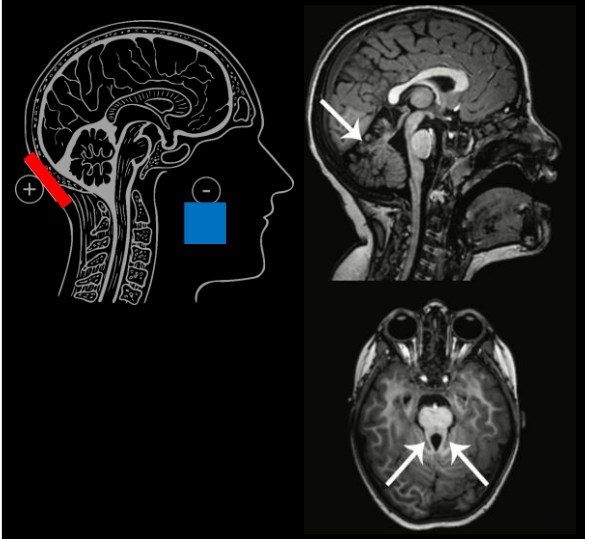

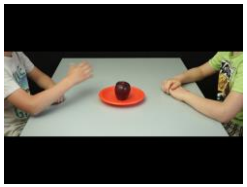

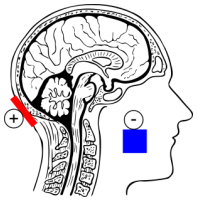

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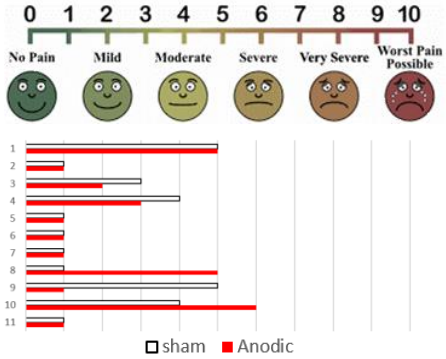
recruitment still ongoing

Tolerability measures



Preliminary results…

Can ctDCS boost social prediction abilities in cerebellar malformation?

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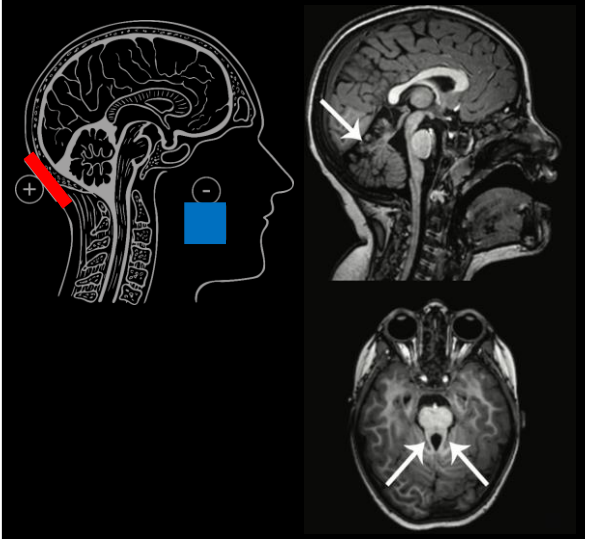

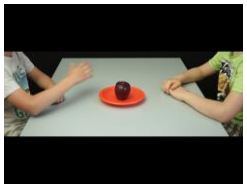

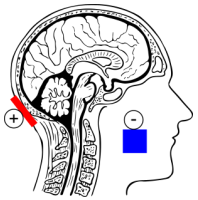

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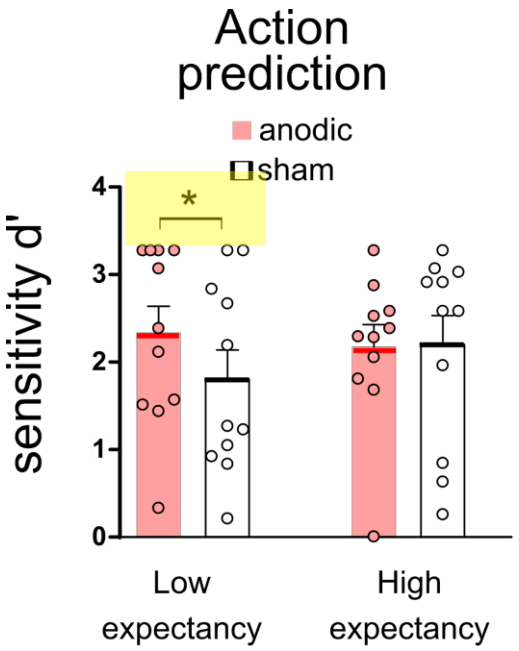

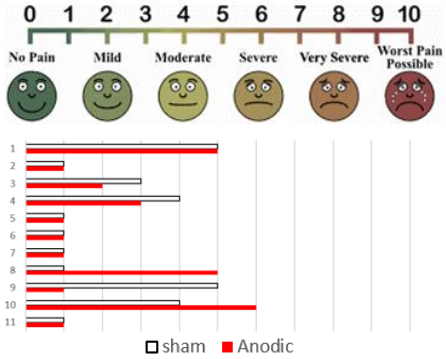

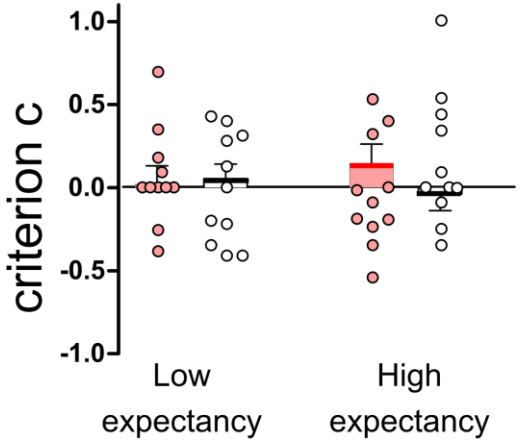

Preliminary results…

Sensitivity d':
Stimulation × Expectancy = $F_{1,10}$ 5.17; $p<.05$; $\eta^2_p = .34$

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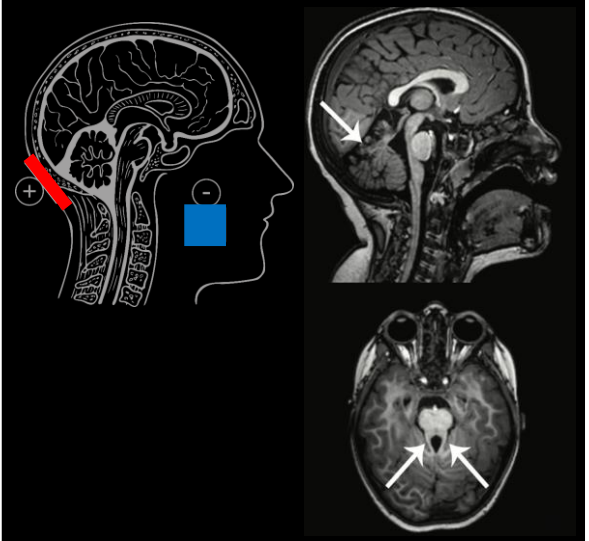
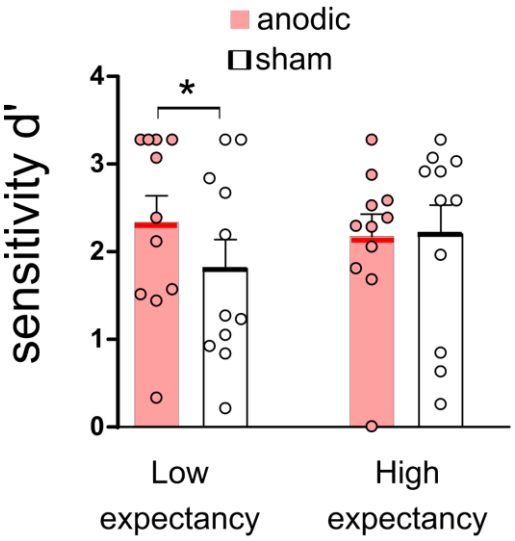
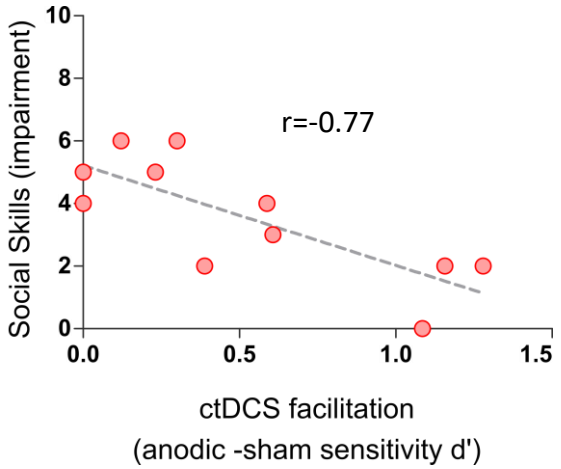


ctDCS effects on Action prediction abilities & Autistic quotient





Research articles

Contextual priors do not modulate action prediction in children with autism

Amoruso et al., 2019

What's next

Testing the effects of multiple session treatment

and the generalization of the social prediction improvement

in everyday life.

NIH U.S. National Library of Medicine

ClinicalTrials.gov

Thank you!

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