Stimulation of the ventrolateral prefrontal cortex speeds up evidence accumulation in conflictual-uncertain environments

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Introduction

Evaluation of the available choices, an integral step in decision-making, leads to the selection of the optimal and most rewarding one.

Choice features such as value and reward-likelihood, form the basis for constructs such as

- *Conflict*- easy or difficult (difference between reward probabilities of the stimuli-pairs) and
- *Uncertainty*- low, medium, or high (inverse U-shaped probability-uncertainty function).

In a previous analysis, using the 2-step sequential learning task and hierarchical drift diffusion model, we previously extracted the computational estimates of decision making and showed that in a context where choices are difficult and return being uncertain ***(difficult-uncertain)*** (Mandali *et al* 2019)

- Healthy Volunteers accumulate less evidence as the winning probability is at chance level
- Patients with Obsessive-compulsive disorder (OCD) showed deficits with low levels of drift rate

The ventrolateral prefrontal cortex (vlPFC) has been implicated in various processes ranging from uncertainty processing to washing behaviours in OCD.

Aim

To target the vlPFC using trans-cranial magnetic stimulation, to modulate decision-making behaviours in the context of conflict and uncertainty.

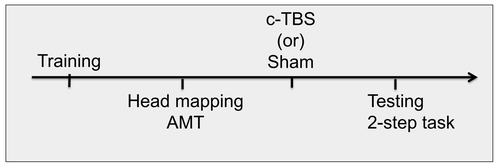
Method

Non-invasive stimulation protocol design

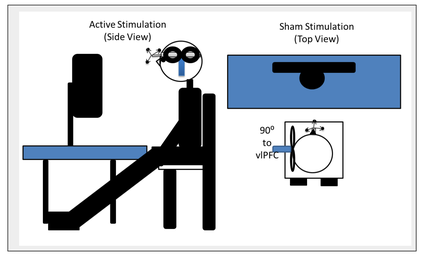
N=60 (30 per group), randomized single blinded design

Single session of Continuous Theta Burst Stimulation (c-TBS): 600 pulses (40 sec) using 80% Active motor threshold or Sham: 90° shift of the coil

Study Design



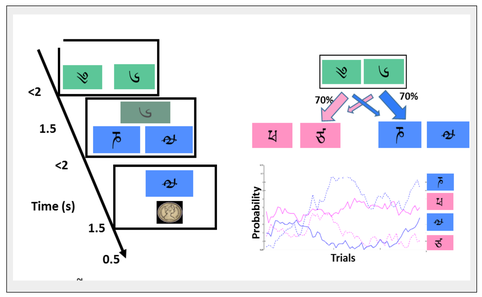
A pictorial representation of the TMS coil orientation and the set-up



Experimental Paradigm

We used the 2 stage sequential learning task (Daw *et al* 2011), previously used to study and distinguish goal-directed and habit behaviour

2-step Sequential Learning Task



Using the second stage reward probabilities of the choices, we calculated

Conflict (C)- easy or difficult (Based on the difference between reward probabilities of the stimulus-pairs)

$$C_j^i = 1 - \frac{|P_{1j}^i - P_{2j}^i|}{\max(|P_{1j}^i - P_{2j}^i|)}$$

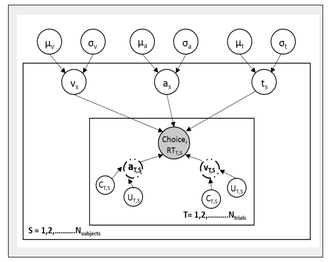
Uncertainty (U)- low, medium or high (Based on an inverse U-shaped probability-uncertainty function).

$$U_{x,j}^i = \sum P_{x,j}^i \, (1 - P_{x,j}^i)$$

Hierarchical Drift Diffusion Model (HDDM)

The above conflict and uncertainty information was used as to extract the parameters: threshold('*a*': amount of evidence accumulated) and the drift rate ('*v*': rate of accumulation)

Pictorial representation of HDDM



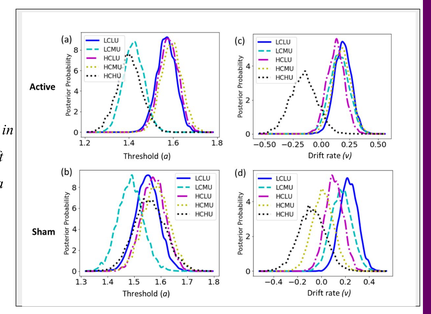
HCHU: High conflict High Uncertainty,
HCMU: High Conflict Medium Uncertainty,
HCLU: High conflict Low Uncertainty,
LCMU: Low Conflict Medium Uncertainty,
LCLU: Low conflict Low Uncertainty

Results

A Bayesian repeated-measures ANOVA on threshold showed a very strong evidence for the main effect of conflict-uncertainty condition (BF_{10} = 5.2 x 10^{10}) and stimulation by condition interaction (BF_{10} = 6.4 x 10^3) but no main effect of stimulation (BF_{10} = 0.46).

HDDM estimates in Active and Sham condition

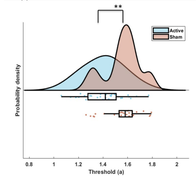
Figure shows the Hierarchical drift diffusion model estimates of threshold in active (a & b) and drift rate (c &d) in Active (a &c) and Sham (b &d) conditions.



A Bayesian Independent samples t-test showed strong evidence (BF_{10} = 77.54) a decreased threshold in active condition

Threshold in Active and Sham condition in difficult-uncertain condition

Figure shows the threshold estimated from the Hierarchical drift diffusion model in active and sham in difficult-uncertain condition



Conclusion

- C-TBS to the vlPFC, possibly causing an inactivation speeded up the decision-making process by decreasing the amount of evidence accumulated.
- This result has implications of using vlPFC as a novel target in treatment of OCD

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