# Does motor variability influence learning in uncertain situations?

## *Better Call Paul*

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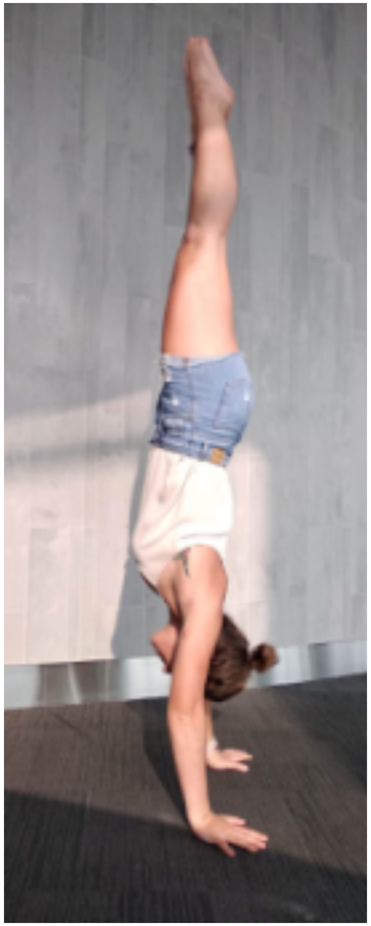
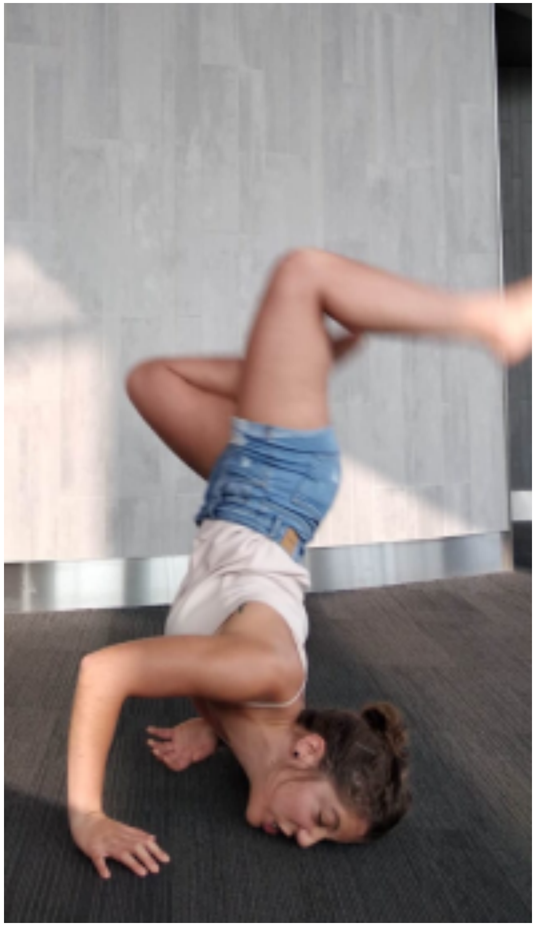
# Phenomenon

My friend





Me…

# Phenomenon

- Motor adaptation is a dynamic phenomenon

- What influences it?
  - individual abilities?
  - Different contexts?

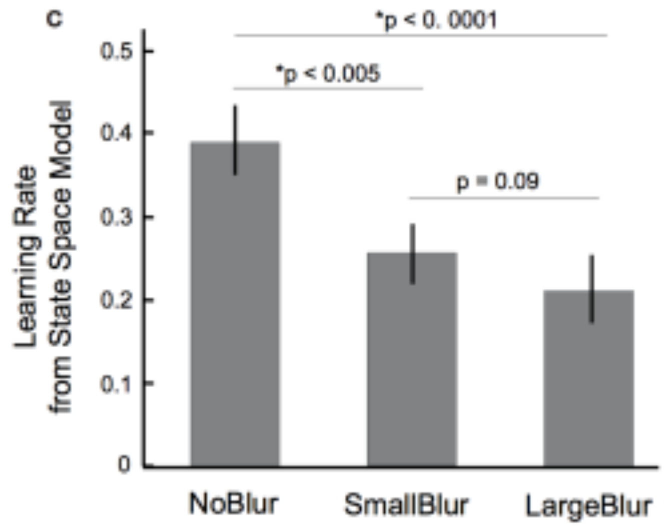
# Research question

Investigating how individual differences in different contexts affect motor adaptation.

***Is the effect of uncertainty perturbation on motor adaptation influenced by initial motor noise?***

# Background

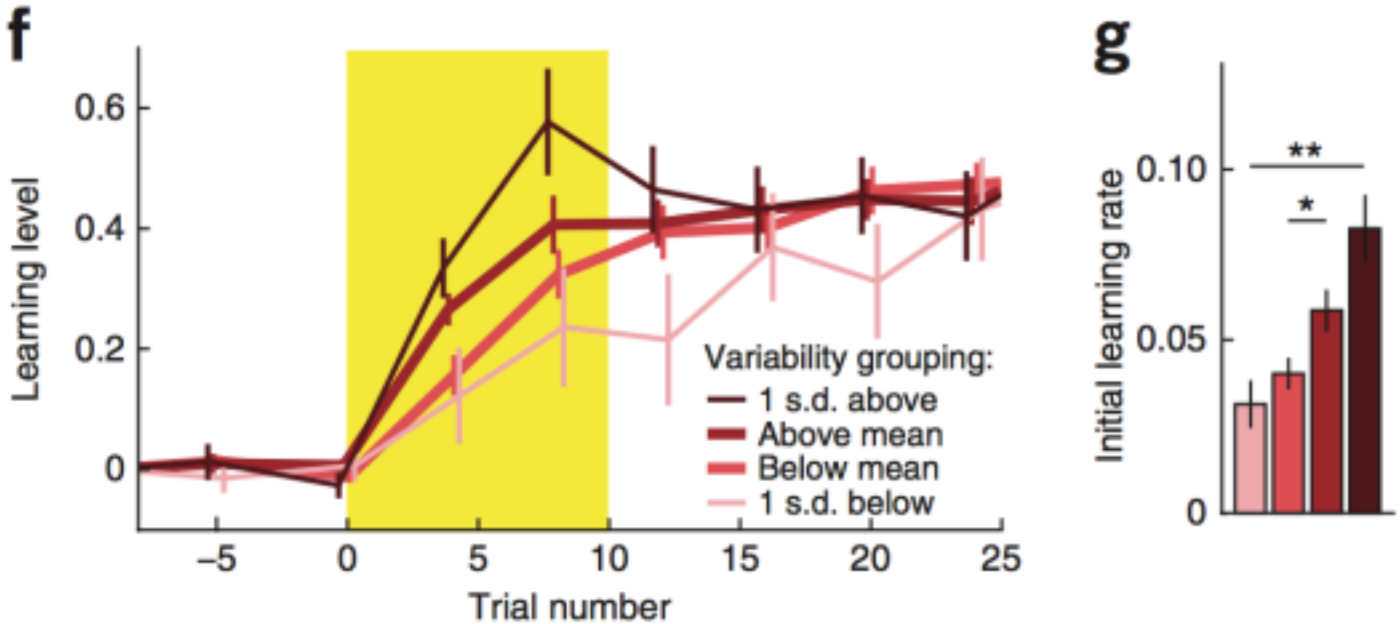
1. Perturbation uncertainty reduces motor adaptation




Wei & Körding, 2010; Körding & Wolpert, 2004

# Background

2. Initial movement variability (motor noise) improves motor adaptation




Wu, Miyamoto, Gonzalez Castro, Ölveczky & Smith, 2014

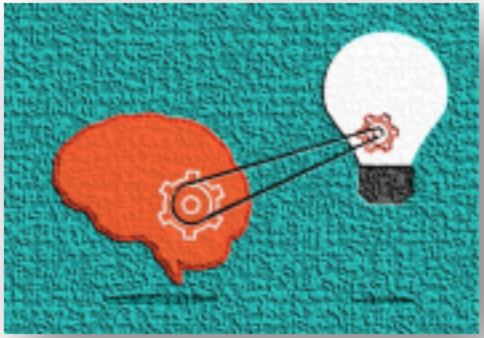
# Hypotheses

High initial motor noise leads to…

1. greater learning rate under high perturbation uncertainty

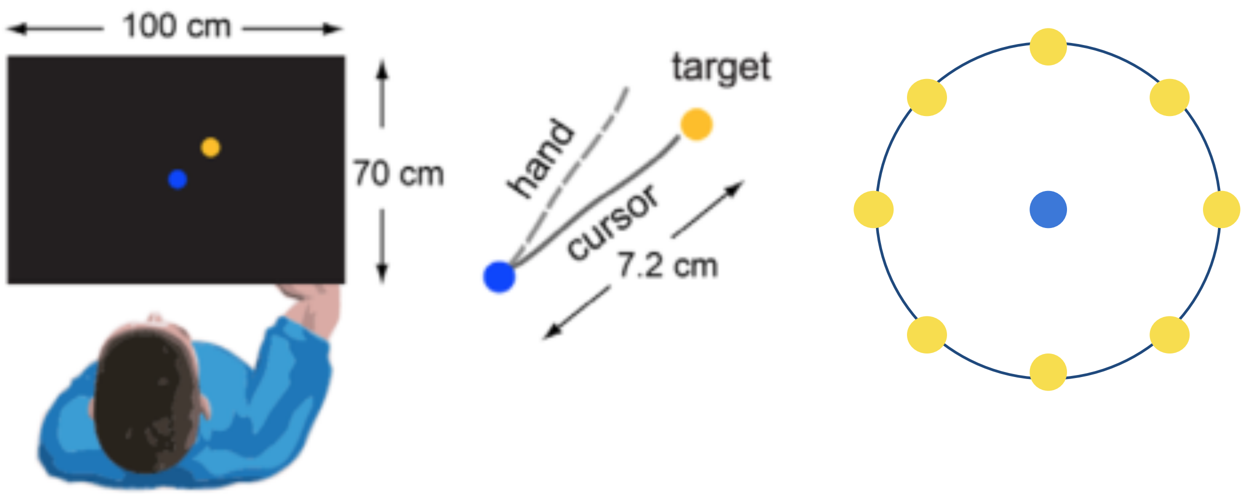
2. greater adaptation level under high perturbation uncertainty

3. smaller increase in motor noise during adaptation



# Task

Fernandes, Stevenson & Kording, 2012



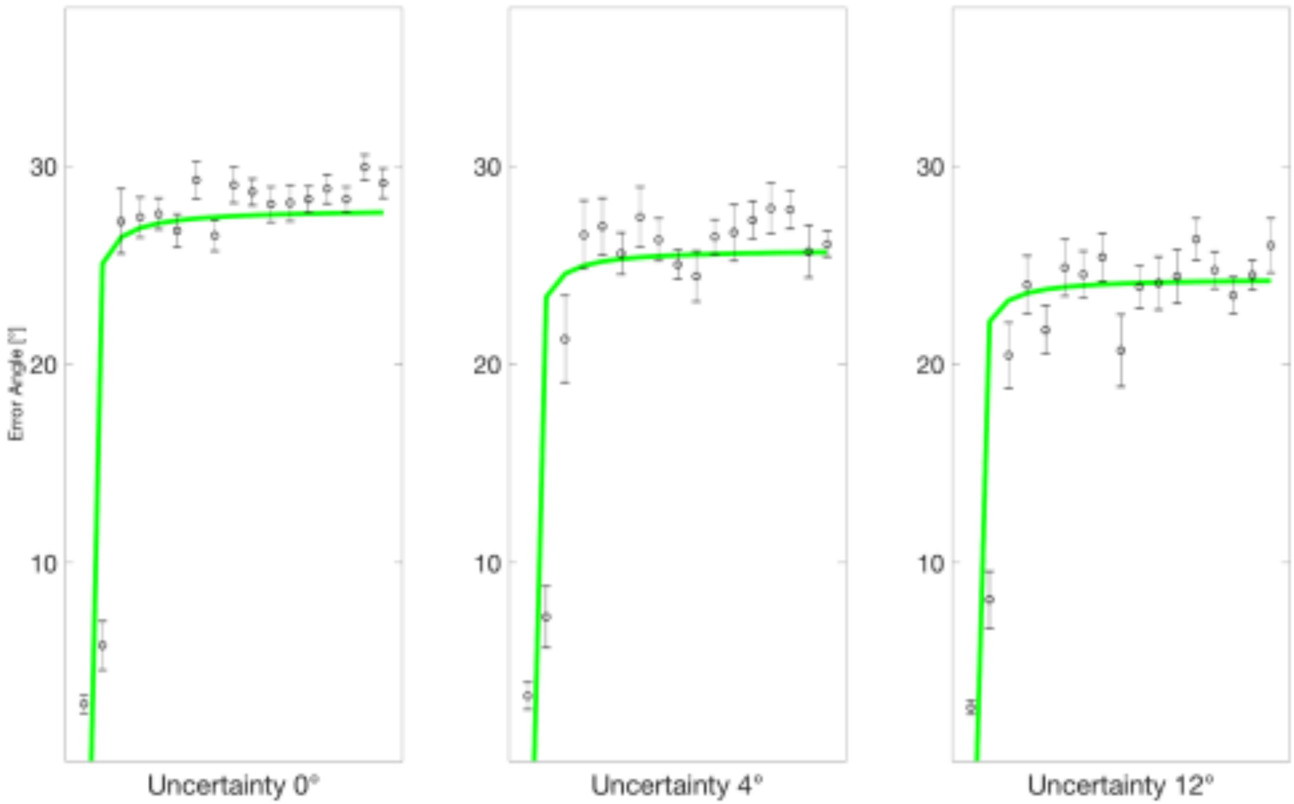

N = 16
Perturbation: +- 30°
with 0, 4 or 12° uncertainty

Each uncertainty condition:

- 15 baseline movements
- 240 learning movements

# Task & Variables

Fernandes, Stevenson & Kording, 2012



# Variables

**Input**
- initial states
- prior
- true movement angular error

**Latent variables**
- movement angle
- perturbation angle

**Output**
- learning rate
- level of adaptation
- motor noise
  (initiated from baseline)

# Selected toolkit

## Adaptive Kalman Filter

- Bayesian model for combining predicted and actual sensory feedback

- Considers environmental uncertainty

- K adjusted by the actual error statistic contained in the model x’ and in the measurement y

# Model schematic

**Input**

Initial Prior

$$A = \begin{bmatrix} 0.998 & \alpha \\ 0 & 0.95 \end{bmatrix}$$

$$R_1 = 1$$

$$Q = \begin{bmatrix} \sigma_m & 0 \\ 0 & \sigma_p \end{bmatrix} = \begin{bmatrix} 0.24 & 0 \\ 0 & 4.96 \end{bmatrix}$$

$$H = [1 \quad 0]$$

$$B = [e^1 \cdots e^m] \sum_{t=1}^{m} \frac{1}{e^t}$$

Initial State

$$x_1 = \begin{bmatrix} \theta_m \\ \theta_p \end{bmatrix}$$

$$V_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Observation

$y_k$

**Adaptive Kalman Filter**

State prediction

$$\hat{x}_k = A.\, x_{k-1}$$

$$\hat{V}_k = A. V_{k-1}. A' + Q$$

$$\hat{R}_k = \hat{R}_{k-1} + B.((e_{k-m:k-1})^2 - \hat{R}_{k-1})$$

State Update

$$S_k = H. \hat{V}_k. H' + \hat{R}_k$$

$$K = \hat{V}_k. H'. S^{-1}$$

$$e_k = (y_{k-n+1:k} - H. \hat{x}_k). n^{-1}$$

$$x'_k = \hat{x}_k + K_k. e_k$$

$$V_k{}' = (I - K_k. H). \hat{V}_k$$

**Output**

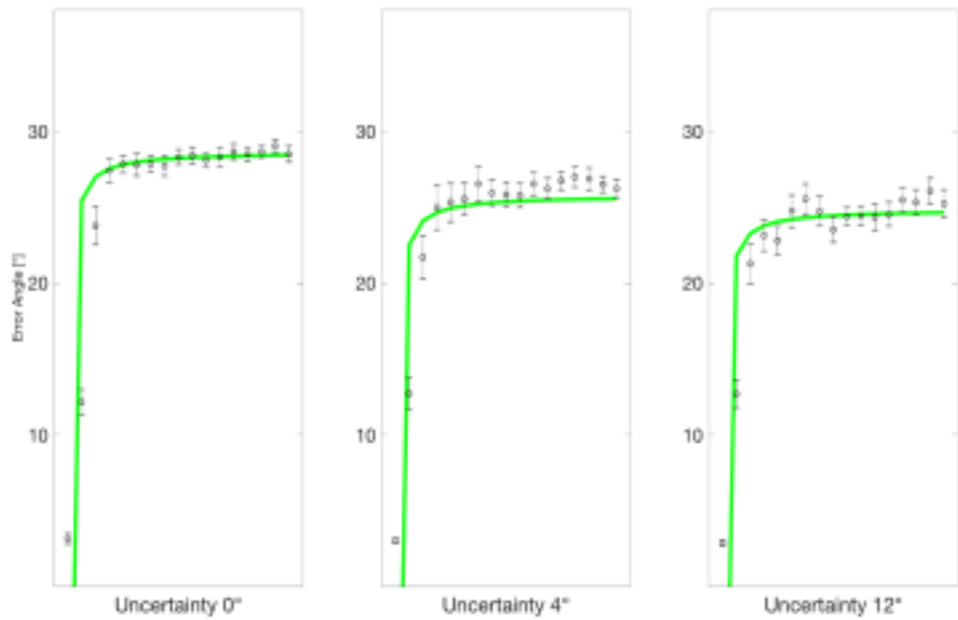
$x$

$V$

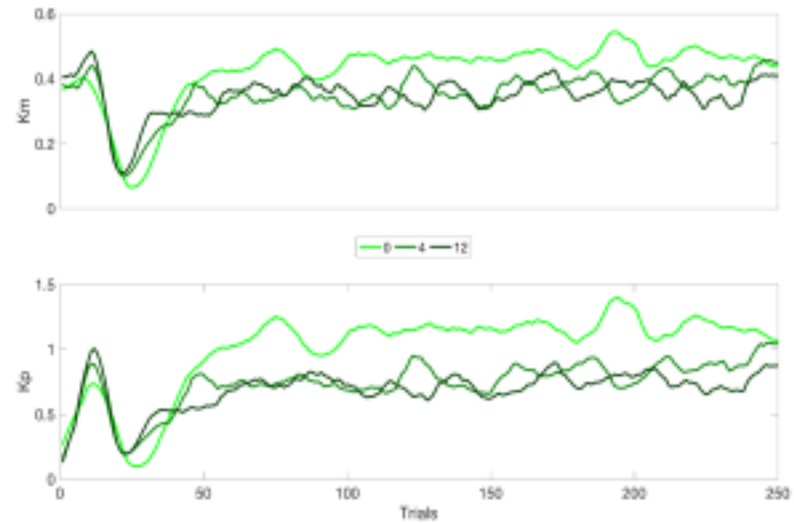
$\alpha$

# Simulations / results

## State movement angle

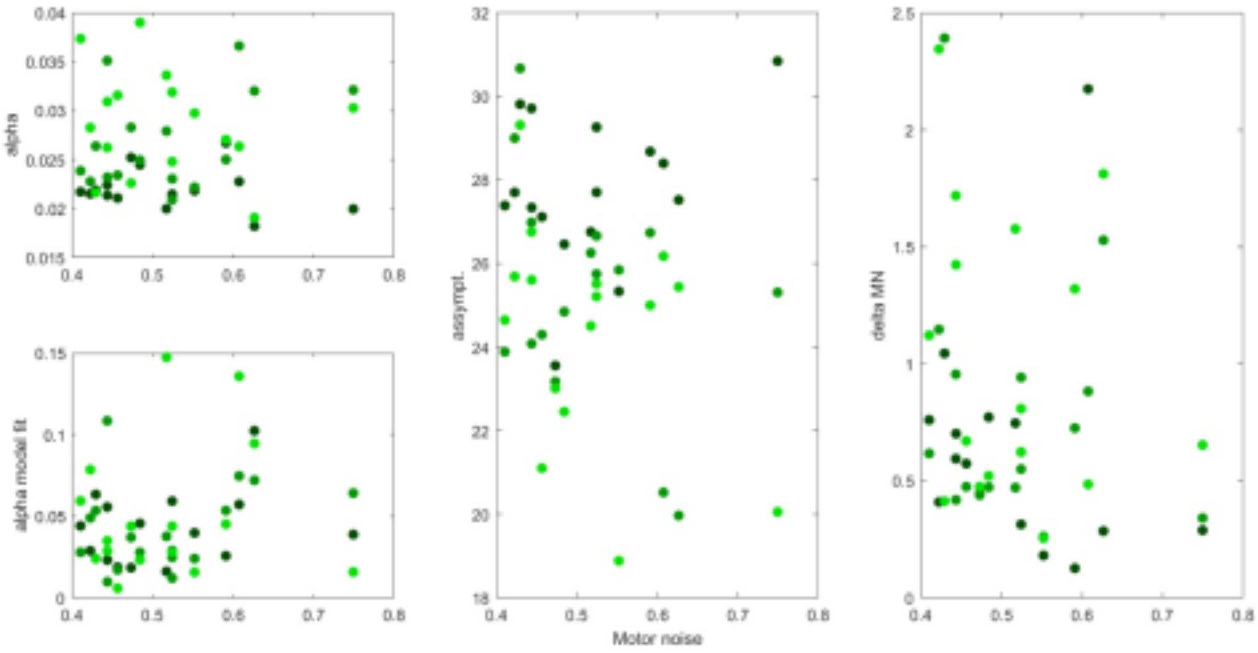



## Kalman Gain



# Simulations / results

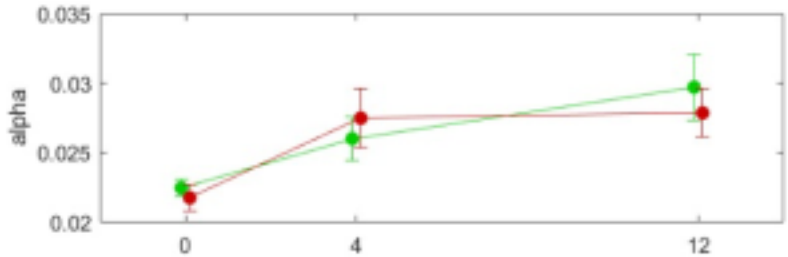
## Learning variables over time

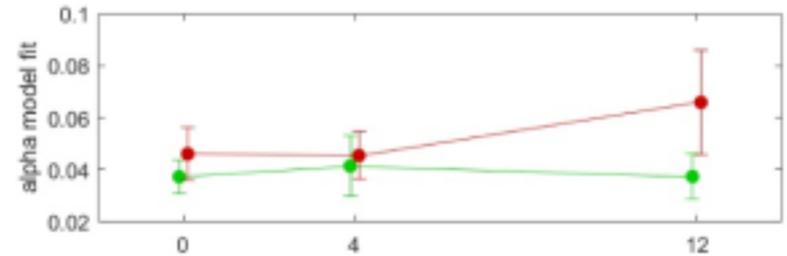


# Simulations / results

High initial motor noise =>

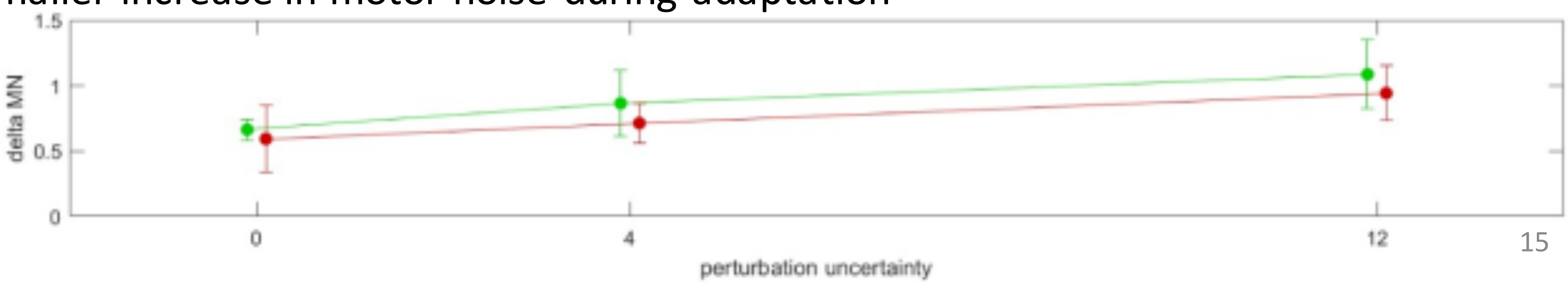
1.. Greater learning rate under high perturbation uncertainty




2. Bigger adaptation level under high perturbation uncertainty


3. Smaller increase in motor noise during adaptation



# Critical model evaluation

- The model does not account for differences in motor planning noise and motor execution noise

  -> motor planning noise might aid adaptation under environmental uncertainty while execution noise reflects lower adaptation ability (van Beers, 2009)

- Insufficient data

  -> more baseline trials needed

  -> no movements to other target directions in between

- Specific criteria to define high and low motor noise

# Summary

- What have you learned?

  - implementation of Kalman filter
  - choice of parameters has a great impact on model outcomes
  - importance of structuring a modelling project
  - benefit from working (and chilling) in a group

# Conclusion