Chudi Thesis

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1.Abstract

2.Introduction

3.Method

3.1. Overview

The current study involved two parts: a behavioural training session lasting around 60 mins and a scanning session lasting around 90 mins with intervals no longer than two weeks. Both parts of the experiments took place at the Wellcome Centre for Human Neuroimaging, University College London. The scanning session was conducted in the 3 Tesla MRI scanner. The ethics of the current study was approved by XX.

3.2. Participants

XX healthy participants were recruited, xx completed the behavioural training session and xx completed the scanning session. According to the preregistration exclusion criteria (see section 3.6. below for details), in total data from 25 participants were included in the final analysis. Participants received cash payments as compensation for their time, £10 for the behavioural session and £20 for the scanning session. To motivate participants to perform their best in our tasks, we also offered bonus payment for good performance and accurate confidence ratings (see procedure below for details on bonus calculation).

3.3. Experimental Procedure

3.3.1. Behavioural session

During behavioural training session, participants first received introductions of the study, including general procedure, ethic and data protection protocols. The structure of the three tasks (see fig.4 for the schematic representation) were explained to participants as following:

- Detection task: On half of the trials, a noisy grating will appear after the fixation cross and on the other half there would be no grating shown and you need to decide whether there was a grating present.
- Discrimination task: A grating will appear on the screen every few seconds after the fixation cross, which will be tilted clockwise in half of the trials and anticlockwise in other half. Participants were asked to decide which direction the grating was tilted to.
- Tilt recognition task: A grating will appear on the screen every few seconds after the fixation cross, which will be tilted (to any direction) in half of the trials and vertical in other half. Participants were asked to decide whether the grating was tilted or vertical.
- Confidence rating: In all three tasks, immediately after making a choice, you need to indicate how confident you are in your decision by changing the size of the circle.

This session contains a practice block, a calibration block and several training blocks for all three tasks. The response mapping will be counterbalanced between blocks, such that an index finger press will be used to indicate a clockwise tilt on half of the trials, and an anticlockwise tilt on the other half. Similarly, in half of the tilt recognition trials the index finger will be mapped to a vertical response, and on the other half to a tilted response. Lastly, in half of the detection trials the index finger will be mapped to a yes ('target present') response, and on the other half to a no ('target absent') response. To avoid size-related effect on confidence rating, participants were divided into two groups such that for half participants bigger circle corresponds to higher confidence level and for the other half smaller circle corresponds to higher confidence level.

During this session, each participants performance was controlled around 70 % accurate, by manipulating the task difficulty independently for the three tasks. This will be achieved by using the common 1 up 2 down staircase procedure on stimulus visibility (discrimination and detection task) and on the standard deviation of the orientation distribution (tilt recognition). Participants were not invited back to continue the scanning session if: 1.) their accuracy were lower than 60% or higher than 80%; 2.) had strong response bias, i.e. used the same response in more than 80% of the trials; 3.) had strong confidence bias, i.e. the same confidence level was reported for more than 90% of the trials.

3.3.2. Scanning session

The structure of the three tasks were the same as behavioural session. To motivate participants perform we offered bonus in addition to the baseline payment for the scanning session. Bonus is calculated use following rule:
bonus=£$\frac{\overrightarrow{accuracy}.\overrightarrow{confidence}}{200}$. Where $\overrightarrow{accuracy}$ is a vector of 1 and -1 for correct and incorrect responses, and $\overrightarrow{confidence}$ is a vector of integers in the range of 1 to 6, representing confidence reports for all trials. The rule for bonus calculation was explained to participants in both sessions. The scanning session started with a calibration phase to further calibrate participants performance during which time the structural scan for each participant was also obtained. At scanning, 10 discrimination and detection blocks were presented in 5 scanner runs.

3.4. Overview

After a temporal rest period of 500-4000 milliseconds, each trial will start with a fixation cross (500 milliseconds). The target was then presented on the screen for 500 milliseconds. In all three conditions, stimuli will consist of 10 grayscale frames presented at 20 frames per second within a circle of diameter 3°. Stimuli will be generated in the following way:

- Generate 10 grayscale frames (F ... F), each an array of 142 by 142 random luminance values.
- Create a 142 by 142 sinusudial grating (24 pixels per period, random phase). The orientation of the grating is determined according to the trial type.
- The grating visibility for frame i is $pi = v \times exp(-|i-5|/2)$ with v being the visibility level in this trial (0 for target-absent trials).
- For each pixel in the frame , replace the luminance value for this pixel with the luminance value of this pixel in the grating with a probability of.

3.5. Scanning parameters

Scanning took place at the Wellcome Centre for Human Neuroimaging, London. The structural images were obtained using an MPRAGE sequence (1x1x1 mm voxels, 176 slices, in plane FoV = 256x256 mm 2), followed by a double-echo FLASH (gradient echo) sequence with TE1=10ms and TE2=12.46ms (64 slices, slice thickness = 2 mm, gap = 1 mm, in plane FoV= 192×192 mm 2, resolution = 3×3 mm 2) that were later used for field inhomogeneity correction. Functional scans were acquired using a 2D EPI sequence, optimized for regions near the orbitofrontal cortex (3.0x3.0x3.0 mm voxels, TR=3.36 seconds, TE = 30 ms, 48 slices tilted by -30 degrees with respect to the T¿C axis, matrix size = 64x72, Z-shim=-1.4).

4.Results

4.1.Performance across threee tasks

Detection (accuracy= 0.78, d'= 1.62), discrimination (accuracy= 0.77, d'= 1.60) and tilt recognition (accuracy = 0.77, d'= 1.60) was similar. A one-way ANOVA failed to detect a significant difference between the accuracy of these three tasks $F(2, 72) = 0.47$, $MSE = 0.00$, $p = .629$, $\hat{\eta}^2_G = .013$ and d' (F= 0.03, p= 0.98; see Figure 1)).

The probability of responding YES in detection was 0.46 ($\pm$ 0.07), and was significantly different from 0.5 (ADD T TEST RESULTS). The probability of responding CLOCKWISE was 0.51 ($\pm$ 0.11) and was not significantly different from 0.5. For the tilt recognition task, the probability of responding TILTED was (0.43 $\pm$ 0.07).

Response time was faster for correct response (1st quartile= 866.66, median= 916.63, 3rd quartile= 951.57 milliseconds) than incorrect responses (1st quartile= 925.50, median= 1000.10, 3rd quartile= 1075.16 milliseconds). A one-way analysis of variance failed to detect a significant overall effect of responses type in detection (YES vs. NO, t=0.44 p=0.66), discrimination (CLOCKWISE vs. ANTICLOCKWISE, t=0.82, p= 0.41) and tilt recognition (VERTICAL vs. TILTED, t=-1.69, p= 0.09) on response time.

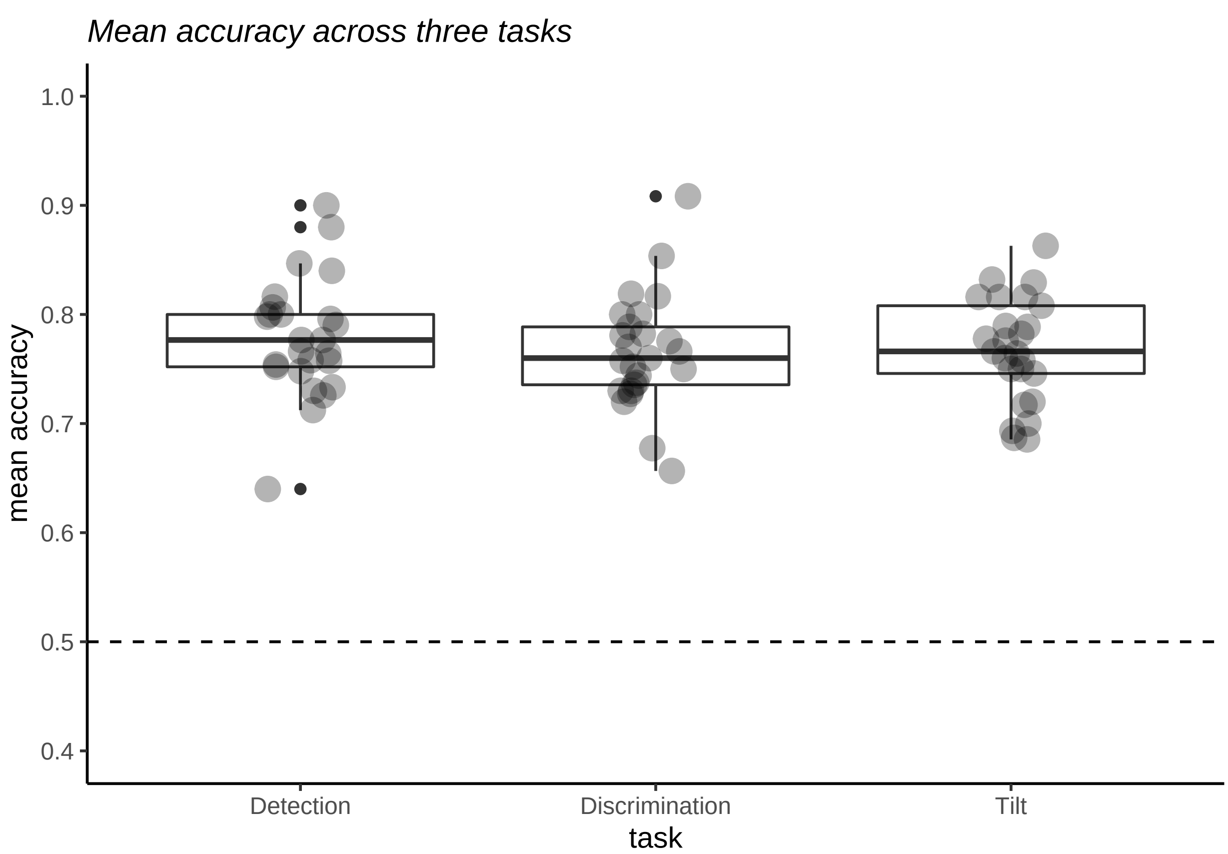
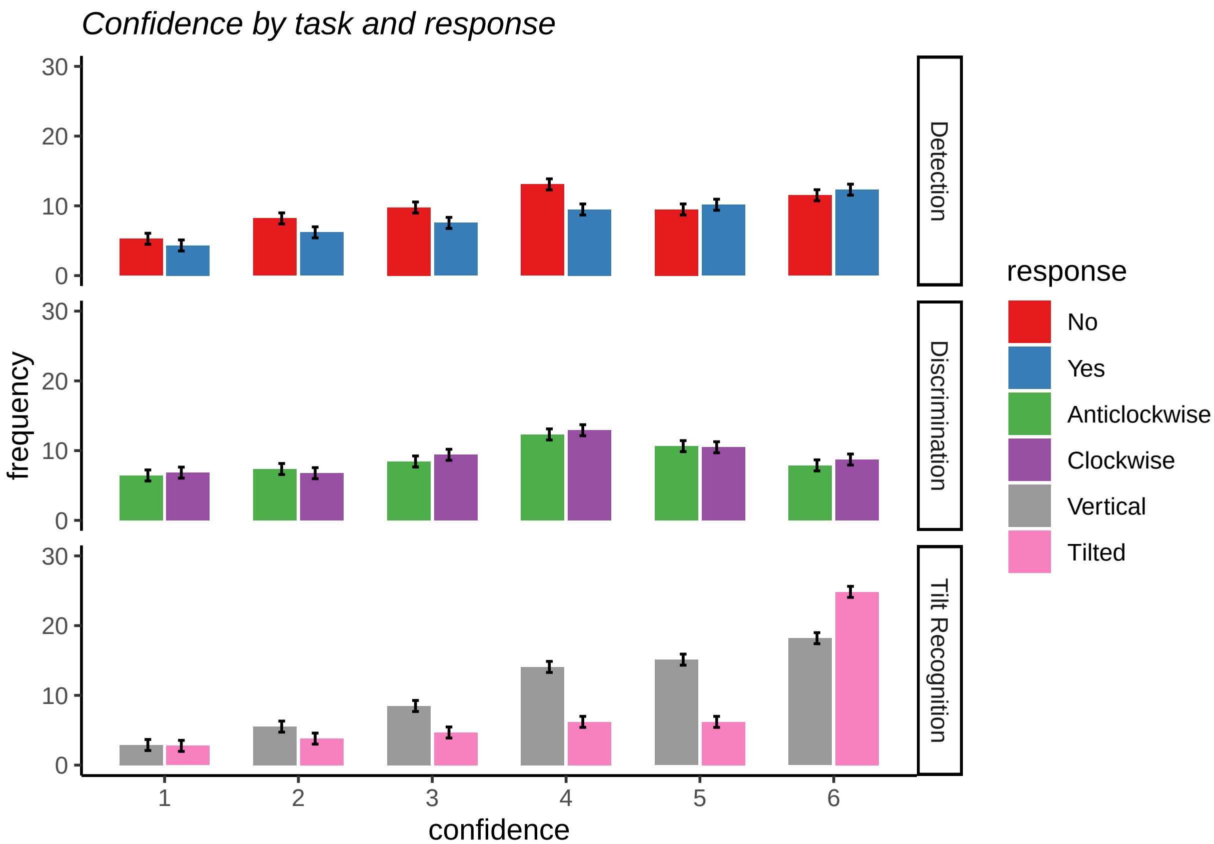
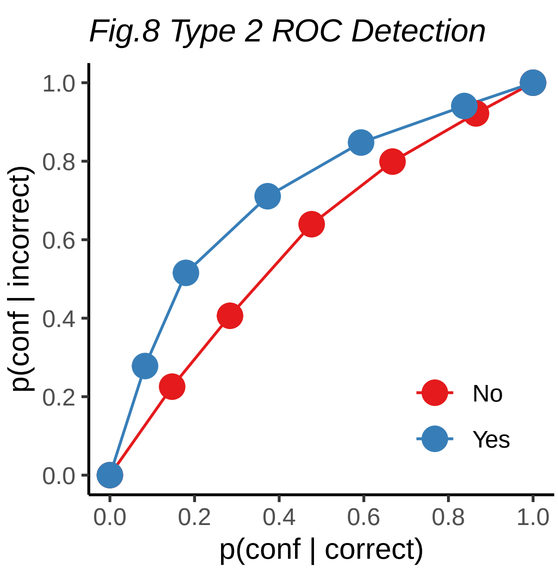


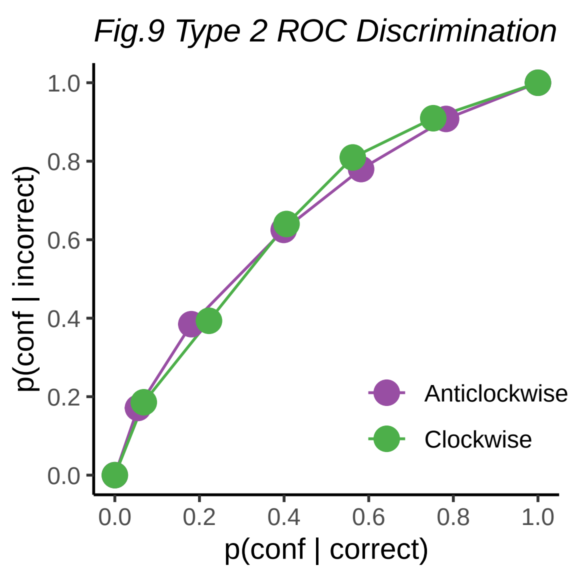
Figure 1: Mean accuracy across three tasks

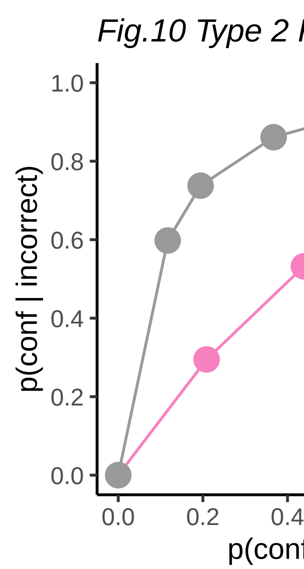
4.2.Confidence distributions Within detection, a significant difference in mean confidence was observed between YES (target present) and NO (target absent) responses (see Fig.4 above) (t=-3.27, p = < 0.001) , such that participants are more confident in their YES responses than NO response and a statistical significance was also observed in the tilt recognition task between TILTED and Vertical response (t=-6.23, p = < 0.001; see Figure **??**).



4.4.Metacognitive sensitivity

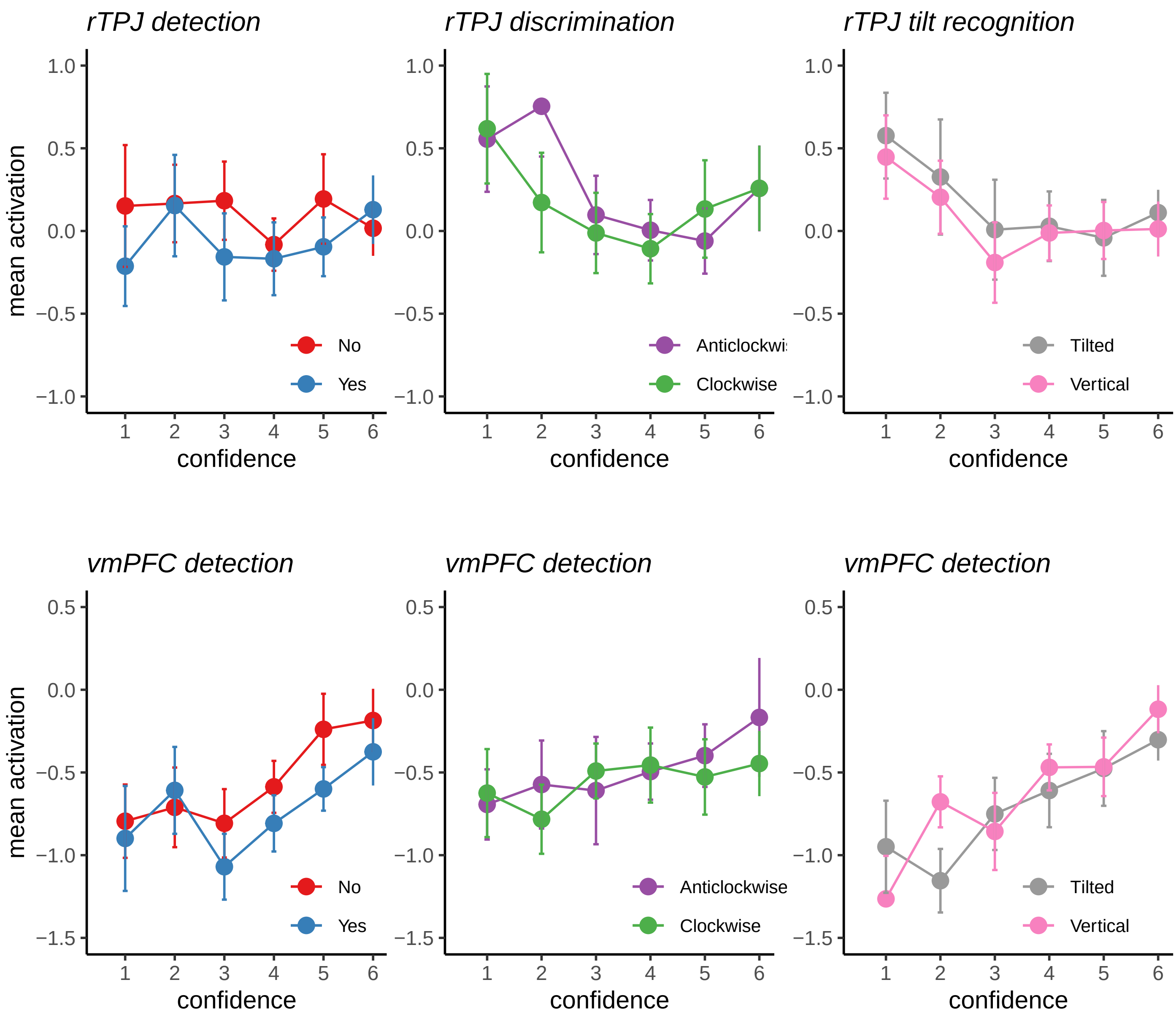


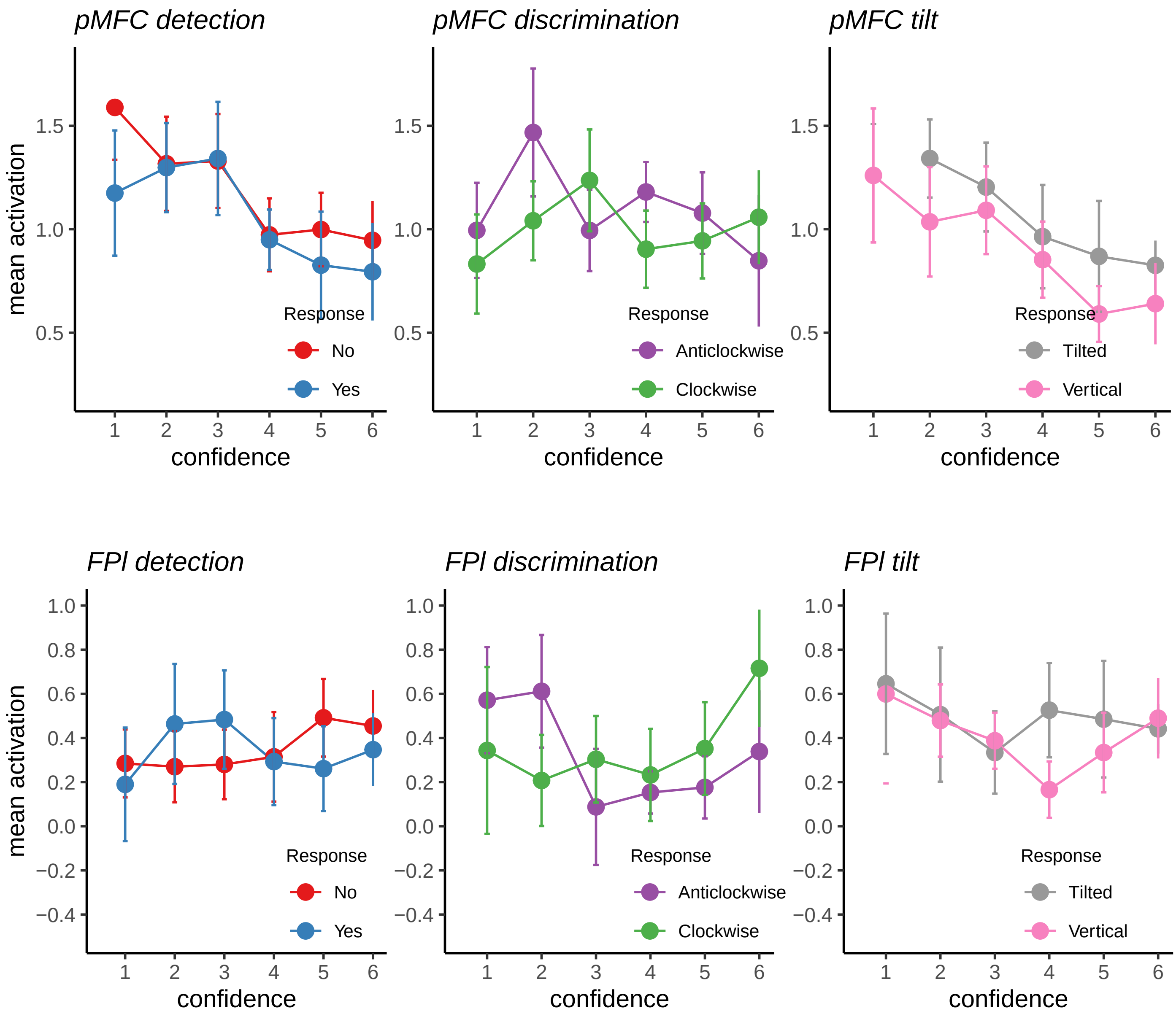




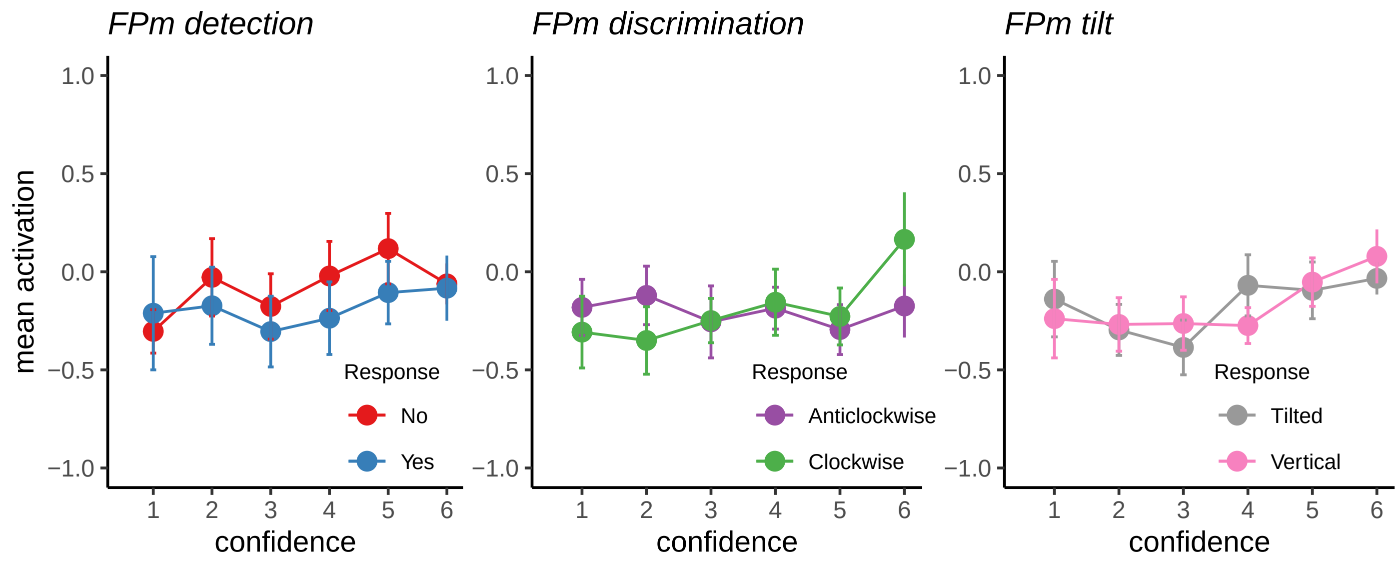
Metacognitive sensitivity, which is quantified as the area under Type 2 ROC curve, is significantly higher for Yes (0.72) than No (0.60) response. Similar pattern is observed in the tilt recognition task, where the AUC is significantly higher for Tilted (0.83) than Vertical (0.57) responses. This suggest that participants confidence ratings are more diagnostic to accuracy in the judgments of a target stimulus being pressent than being absent. Similarly, the correct judgments of a stimulus being tilted is better reflected by partcipants' confidence ratings than the correct judgments of a stimulus being vertical.

4.5. BOLD signal in ROIs





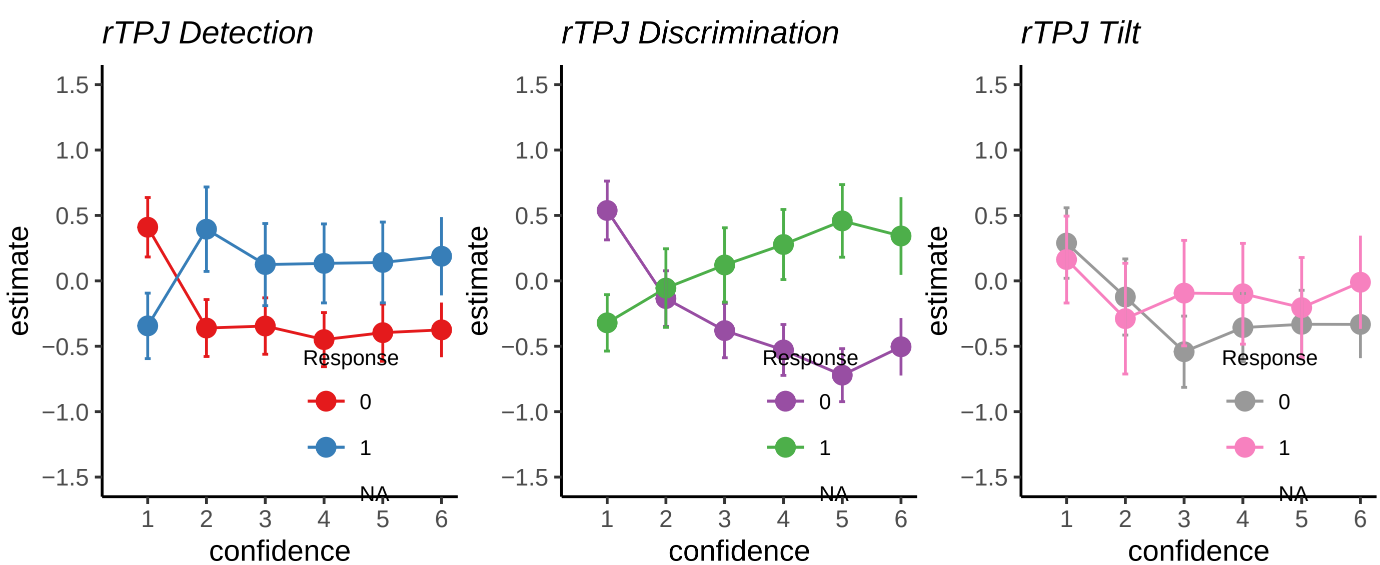
pMFC detection
pMFC discrimination
pMFC tilt
mean activation
1.5
1.0
0.5
1
2
3
4
5
6
confidence
Response
No
Yes
Response
Anticlockwise
Clockwise
Response
Tilted
Vertical
FPl detection
FPl discrimination
FPl tilt
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4

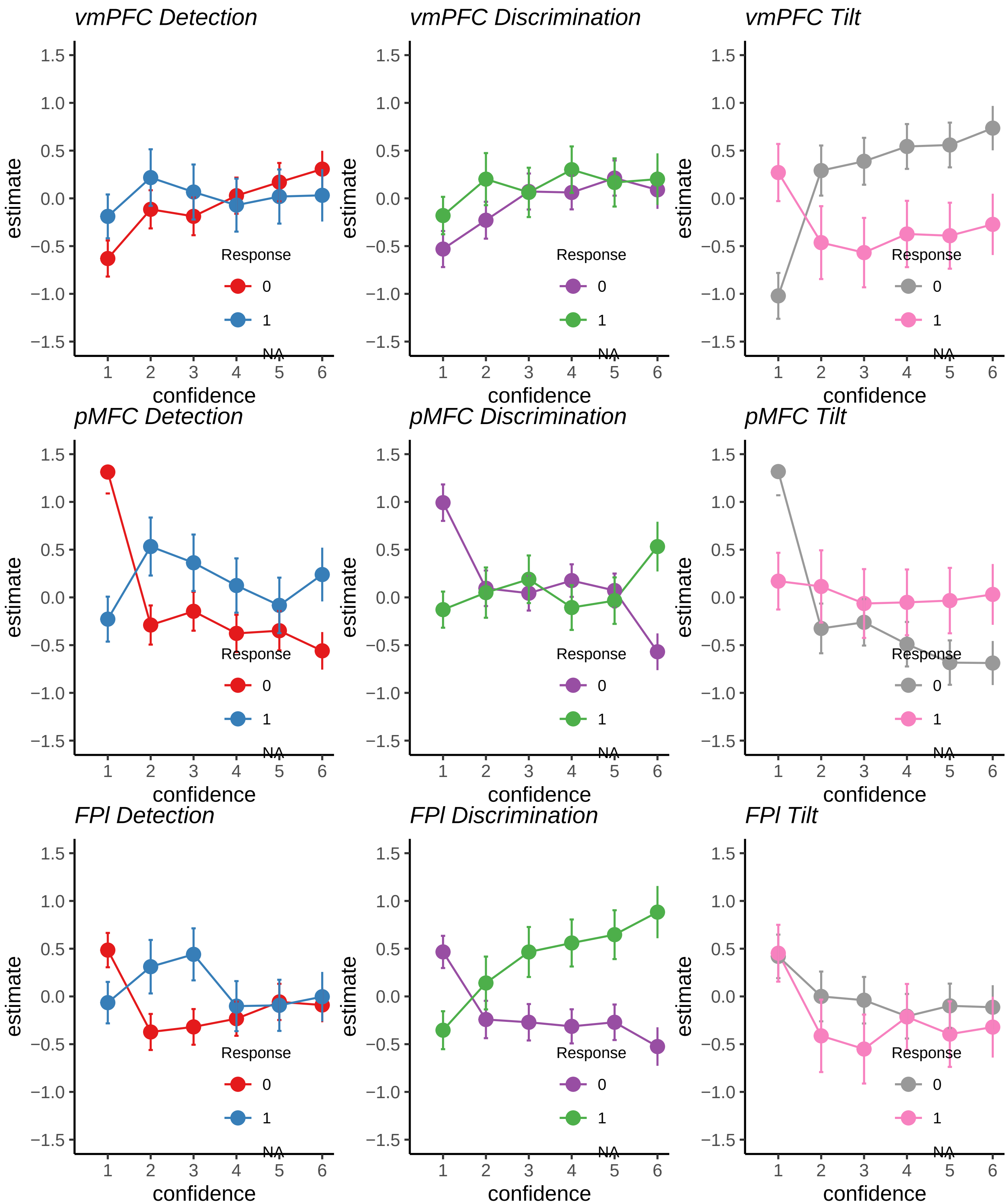


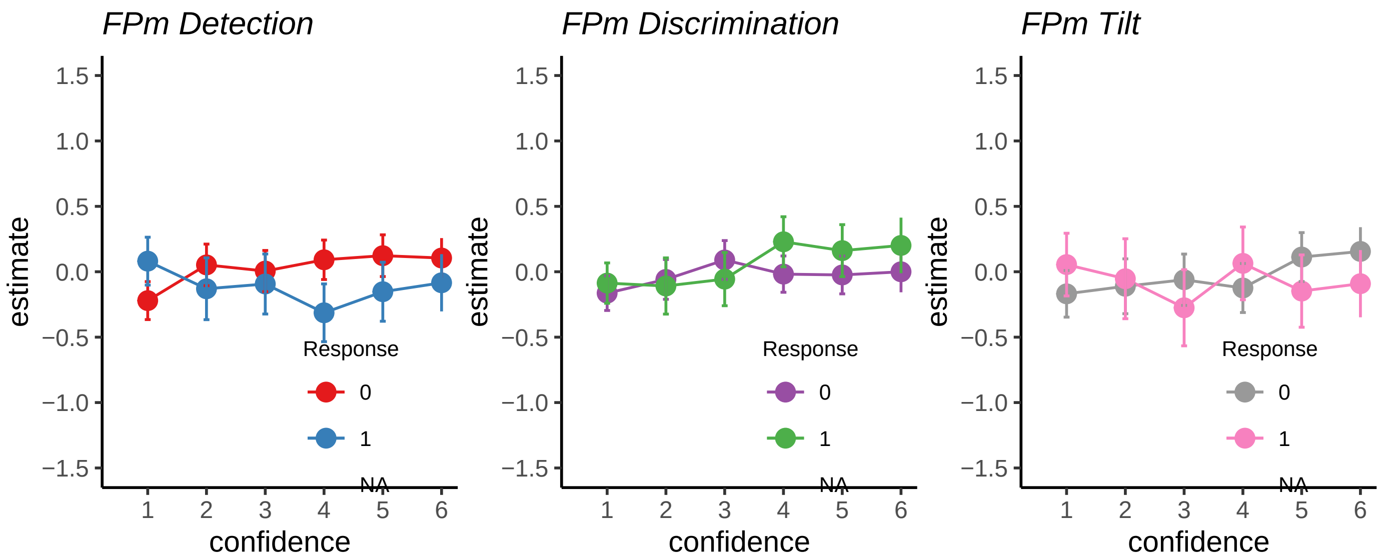
Effect of confidence on BOLD signal in ROIs

From our data, negative linear confidence-related effects were observed in right Temporoparietal Junction (rTPJ) (β=-0.06, p=0.019), Posterior Medial Frontal Cortex (pMFC)(β=-0.10, p=$<$ 0.001), as well as polsitive linear correlation between confidence and BOLD signals in Ventromedial Prefrontal Cortex (vmPFC)(β=0.12, p=$<$ 0.001), Medial Frontopolar Cortex (FPm)(β=0.04, p=0.007).

To investigate whether linear effects of confidence on BOLD signal were influenced by the type of task (Detection vs. Discrimination vs. Tilt recognition) and/or reponse (Yes vs. NO; Clockwise vs. Anticlockwise; Vertical vs. Tilted), linear models with interactions were tested. The effects of confidence failed to show a significant difference between three tasks in all ROIs (all p values $>$ 0.23). No sognificant effect was observed between Yes and No response in detection (all p values $>$ 0.11), between Clockwise and Anticlockwise responses in discrimination (all p values $>$ 0.33) or between Vertical and Tilted responses in tilt recognition (all p values $>$ 0.14).




vmPFC Detection
vmPFC Discrimination
vmPFC Tilt
pMFC Detection
pMFC Discrimination
pMFC Tilt
FPl Detection
FPl Discrimination
FPl Tilt
estimate
confidence
Response
0
1
NA
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
1
2
3
4
5
6



Citation

(Denison et al. 2018)(Mazor, Friston, and Fleming 2020)

Reference

Denison, Rachel N., William T. Adler, Marisa Carrasco, and Wei Ji Ma. 2018. "Humans Incorporate Attention-Dependent Uncertainty into Perceptual Decisions and Confidence." *Proceedings of the National Academy of Sciences of the United States of America* 115 (43): 11090–5. https://doi.org/10.1073/pnas.1717720115.

Mazor, Matan, Karl J Friston, and Stephen M Fleming. 2020. "Distinct Neural Contributions to Metacognition for Detecting, but Not Discriminating Visual Stimuli." Edited by Thorsten Kahnt, Joshua I Gold, and Michael Graziano. *eLife* 9 (April). eLife Sciences Publications, Ltd: e53900. https://doi.org/10.7554/eLife.53900.