Topography of functional organization of beat perception in human premotor cortex: causal evidence from a TMS study

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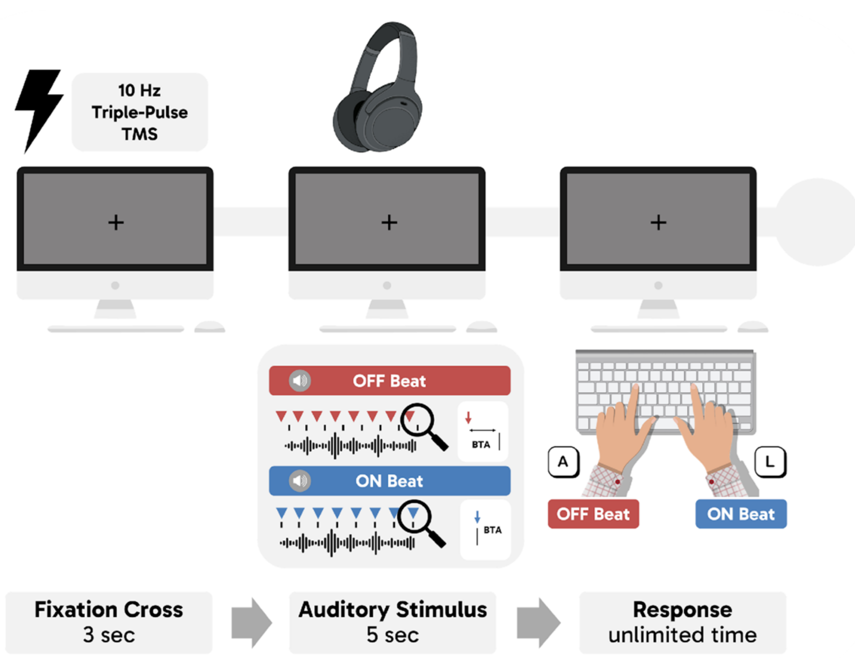
INTRODUCTION

Humans can flexibly extract a regular beat from complex auditory patterns, such as music. When people are **passively listening to rhythmic stimuli**, neuroimaging [1-3] and neurostimulation [4,5] studies **consistently demonstrate the engagement of the dorsal auditory-motor network**. Based on this evidence, several authors have argued that **motor regions such as the M1, PMC and SMA may be critical in generating temporal predictions and transferring this information to auditory regions** to guide perception [6-9].

AIM

Do premotor regions (**PMC e SMA**) have a **causal and active role in beat perception**? Which **specific region**? Are there any **hemispheric asymmetries**?

METHODS



Beat Alignment Test [10]: detect if a superimposed metronome is on-the-beat or off-the-beat of a real musical track

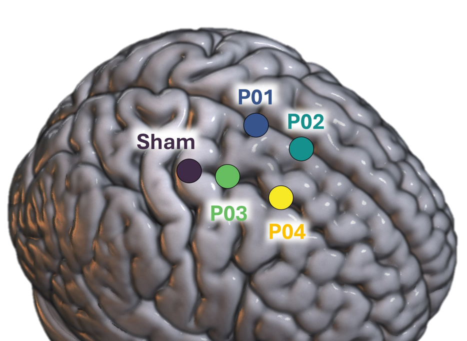
BTA (Beep Track Accuracy) = metronome asynchrony (varies from 50 to 100%). Four levels: .5, .6, .7 & 1.0 (selected based on Behavioural study)

20 tracks

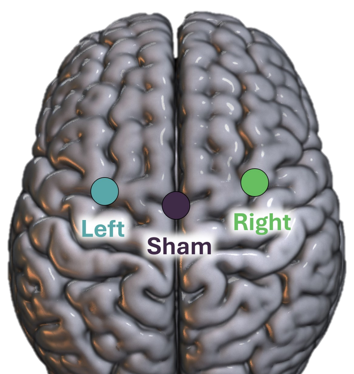
+

Barcelona Music Reward Questionnaire (BMRQ) [11]: questionnaire on music reward sensitivity
20 items (1-5)

Behavioural study	TMS Study 1	TMS Study 2
29 non-musicians (17 F)	40 non-musicians (24 F)	42 non-musicians (25 F)
M(age) = 23.4	M(age) = 23.2	M(age) = 23.5



4 dots grid on PMC e SMA:
Sham = Primary motor cortex (M1)
P01 = Supplementary Motor Area (SMA)
P02 = Pre-SMA
P03 = Dorsal Premotor Cortex (dPMC), caudal portion
P04 = dPMC, rostral portion



The stimulation grid was localized by means of neuro-navigation

DISCUSSION

Results of Studies 1 and 2 indicate that **TMS over the most caudal part of right dPMC significantly impairs asynchrony** detection compared to all other sites.

Results of Study 2 indicate that **this effect is hemisphere specific**, with stimulation over left caudal PMC showing no significant effect on asynchrony detection.

Together these findings demonstrate that **right caudal dPMC is crucial for making the temporal predictions that underlie beat perception**. These results are in line with a number of accounts that have hypothesized that motor regions play an active role in temporal perception [7-9].

We also observed a significant relationship between **individual differences in musical reward sensitivity and asynchrony detection, such that greater reward sensitivity was associated with better perceptual abilities.**

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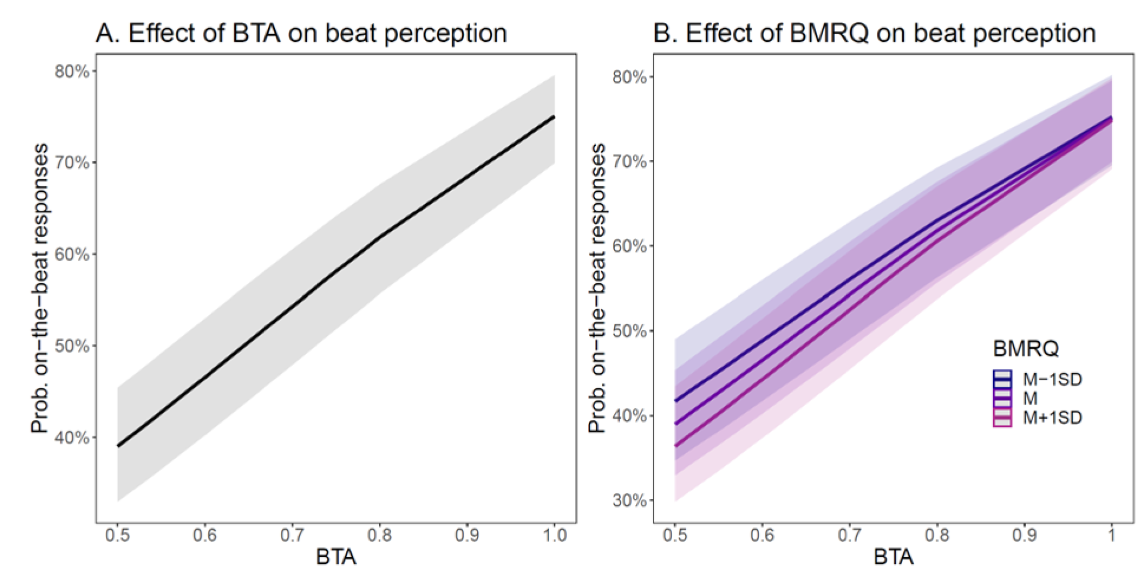
RESULTS

BEHAVIOURAL STUDY

stimuli selection

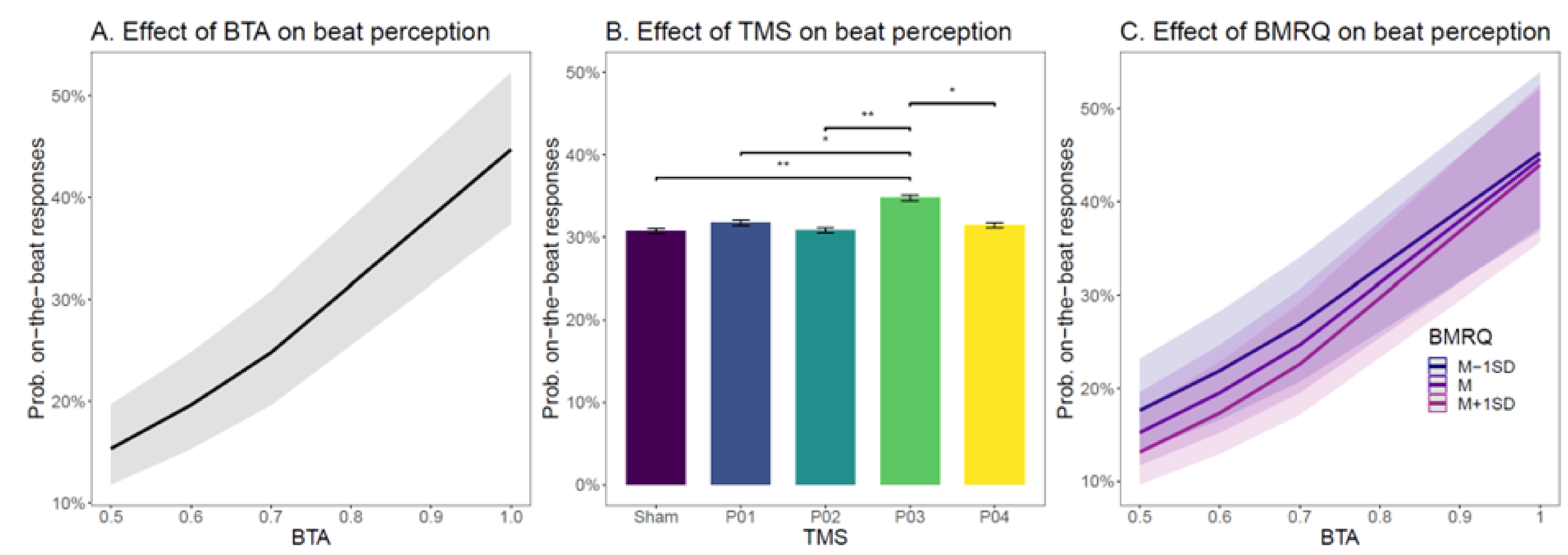


A. Multilevel logistic regression predicting on-the-beat responses based on BTA. We found a significant effect of BTA (b = 3.10, $p < .001$), indicating that **the probability of responding that a stimulus is on-the-beat increases with BTA**, as expected.

B. When including in the model the overall BMRQ score as well as its interaction with BTA, we found a marginally significant interaction between BMRQ and BTA (b = 0.20, $p = .081$). This interaction, albeit not fully significant, indicates **a tendency for participants with a higher musical reward to exhibit a heightened sensitivity to the BTA** (i.e., a steeper logistic regression line).

TMS STUDY 1

mapping the premotor cortex



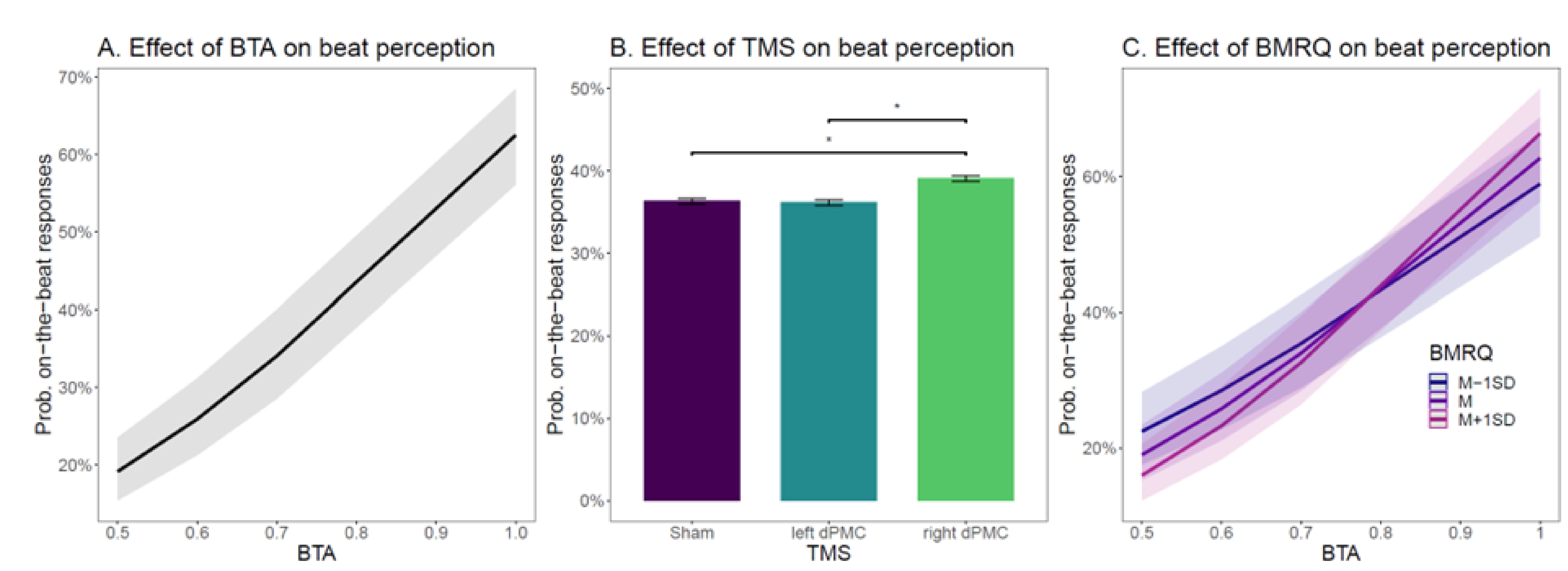
A. In line with the Behavioural Study, the probability of responding that a stimulus is on-the-beat increases with BTA (b = 2.99, $p < .001$).

B. Crucially, stimulating the P03, corresponding to the **caudal part of the dPMC, significantly increases the probability of indicating that the musical stimulus is on-the-beat** (b = 0.22, $p < .001$), compared to the sham control condition and other TMS stimulation sites (all $ps < .035$).

C. When including BMRQ scoring, the significant interaction between BMRQ and BTA (b = .29, $p = .002$) indicates that **participants with a higher musical reward score are more sensitive to the misalignment, indicating more refined rhythmic perceptual abilities**.

TMS STUDY 2

hemispheric differences



A. The probability of responding that a stimulus is on-the-beat increases with BTA (b = 3.91, $p < .001$).

B. We confirmed TMS Study 1 finding: stimulating the **right dPMC significantly increases the probability of indicating that the musical stimulus is on-the-beat** (b = .14, $p = .007$), compared to the sham control condition and the left dPMC (all $ps < .032$).

C. In line with Behavioural and TMS 1 Studies, the significant interaction between BMRQ and BTA (b = .74, $p < .001$) indicates that **participants with a higher musical reward exhibit better performance and higher rhythm perceptual abilities.**

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