Musical rhythm orchestrates neural activity and influences stimulus processing at specific moments in time

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Background

- Neural tracking of environmental rhythm has been shown to enhance perception of stimuli appearing in-synchrony versus out-of-synchrony with the beat.[1-2]
- According to the Oscillation Selection Hypothesis (OSH), rhythm increases neural firing and prioritizes information processing at predicted moments in time (on-beat).[3]
- ERP studies have shown that rhythm influences both early perceptual responses (N1) and later post-perceptual responses (P3) when stimuli appear at predicted (on-beat) moments in time.[4-6]
- Recently, we demonstrated that neural tracking of rhythm also influences memory formation: Participants with stronger neural tracking of rhythm demonstrate better subsequent memory for on-beat vs. off-beat stimuli.[7]
- **An outstanding question is how rhythm influences information processing at the time of stimulus presentation to influence memory formation**.
- Does rhythmic temporal structure influence encoding by modulating neural activity later in the processing stream, around the time of classic subsequent memory effects (Differences in memory (Dm): 400-700ms)? [8]

Hypotheses

1. **Rhythm influences both early perceptual responses (N1) and later post-perceptual responses (P300) associated with stimulus perception and attention.**
2. **In addition, rhythm influences later cognitive components associated with subsequent memory.**

Method

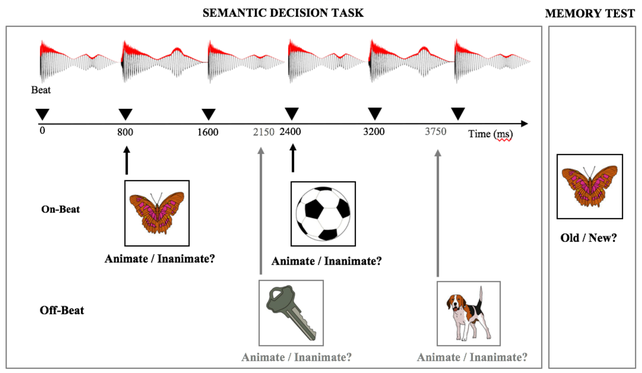
Participants (n=36)

- 33% Male
- Average age: 23 years (*SD* = 3.32)
- Right handed
- No history of neurological illness, substance use, or psychiatric diagnosis

EEG processing

- EEG recorded from 32 channels
- Epochs (-2:2s) locked to stimulus onset
- Baselined from -100:0ms
- ERPs generated for on-beat trials and off-beat trials
  - N1: 77-99ms (based on grand average)
  - P3: 300-400ms[9]
  - Dm: 400-700ms[8]

Paradigm

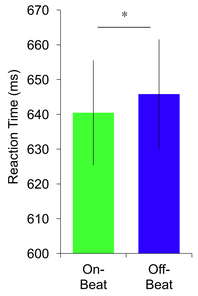


Semantic Decision Task
- 120 images with background music
  - 60 on-beat, 60 off-beat
- Responding if animate or inanimate

Memory Test:
- 180 images total
  - 120 old, 60 new
- Identifying if old or new

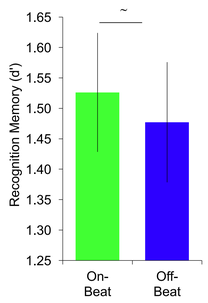
Behavioral Results

Reaction Times at Encoding



- Reaction times are significantly faster for on-beat compared with off-beat

Memory Performance at Test

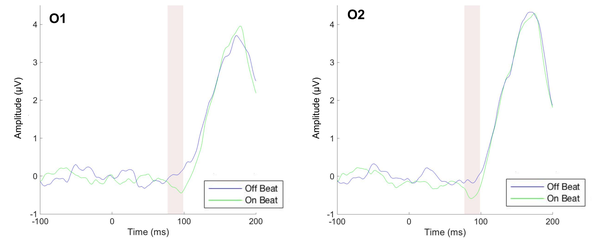


- Memory performance is numerically better for on-beat compared with off-beat

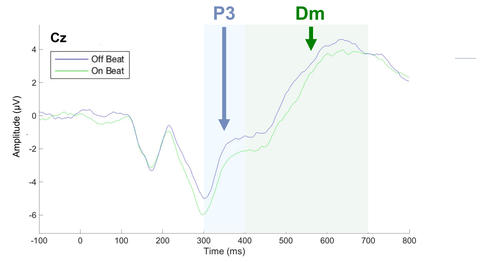
* p < .05, ~ p < .10

ERP Results

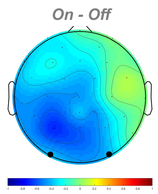
Early ERP: N1



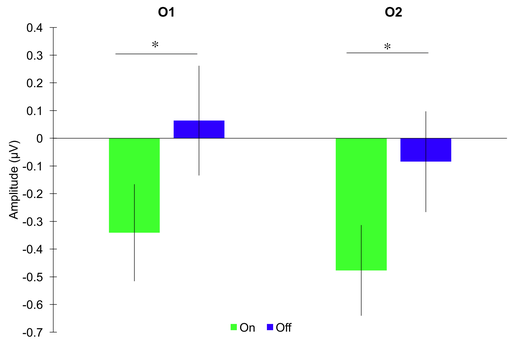
Later ERP: P3 & Dm



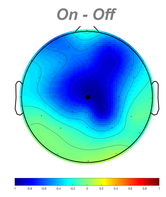
Average N1 Amplitude Differences

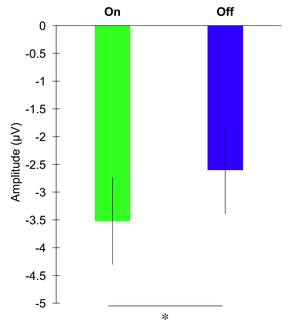


- Significant main effect of timing (on/off)
  F(1,35)=4.77, p=0.036
- No effect of electrode (O1/O2)
- No interaction between electrode (O1/O2) and timing (on/off)



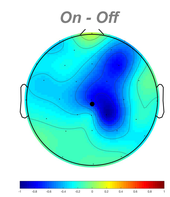
Average P3 Amplitude Differences

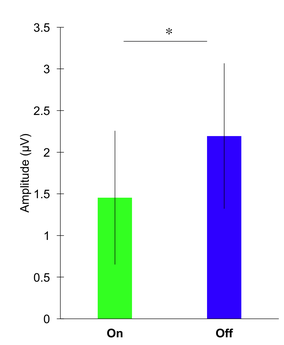




P3 for on-beat < off-beat trials
t(35)=2.983, p=0.005

Average Dm Amplitude Differences





Dm for on-beat < off-beat trials
t(35)=2.322, p=0.026

* p < .05

Conclusions

- **Rhythm influences ERPs associated with early perceptual processing (N1) and later post-perceptual processing (P3). This is consistent with the predictions from OSH.[3]**
- **Modulations in these components could reflect enhanced perceptual processing (N1)[4,8] , reduced need for attentional processing, or reduced degree of surprise (P3)[9] for information presented in synchrony with the beat**
- **Rhythm also influences later cognitive components associated with subsequent memory (Dm). However, surprisingly, we find greater positivity for off-beat information compared with on-beat, which is not consistent with previous findings.[8]**
- **Amplitude differences between on-beat and off-beat stimuli for N1, P3, Dm did not correlate with differences in behavioral performance for on-beat vs. off-beat stimuli (Reaction speed during encoding or subsequent memory performance)**

Outstanding Question: What is the relationship between rhythmic changes in evoked responses and behavior?

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