The Effect of Context on Human Mirror System Integration in Action Understanding

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Background

- Observing the action triggers activation of the brain's sensorimotor system (Catmur, 2014), which maps the physical motion mechanisms as if they were performed by the observer, a process coined as sensorimotor resonance (SMR).
- Concurrently, determining the actor's intent requires inductive inference using higher-order cognitive processing areas (Van Overwalle & Baetens, 2009).
- However, the extent to which the mirroring areas contribute to the inferential process remains unclear (Catmur, 2014, 2015).
- How sensorimotor resonance contributes information, if any, to inferring higher-order action goals has yet to be thoroughly investigated.
- Does sensorimotor resonance contribute necessary information to correctly inferring, for instance, that a gesture of hand-waving indicates greeting rather than leave-taking?
- A possible function of sensorimotor resonance may be to act as a gatekeeper of the information needed for the prediction of the mental goal of an action (Catmur, 2015).
- Given the possibility of such a gatekeeper role, the current research asks how an actor's intent influences the processing of information from sensorimotor resonance and its communication throughout the brain.
- To answer these questions, our study sought to elicit both sensorimotor resonance and inferential processing by manipulating participants' personal involvement in the actions they observe.
- We hypothesized that **as participant involvement increases, sensorimotor resonance and sensorimotor mu complexity would increase**1), with sensorimotor resonance increasing linearly across the time of observation. Secondly, **midfrontal theta activity will only be present during active play conditions temporally following sensorimotor resonance**. Finally, **the global efficiency of the alpha band will be reduced during active gameplay** and predict sensorimotor resonance.

Methods

- EEG was recorded for healthy participants (n=43, males=23)
- In the present study, we utilized the EEG rock-paper-scissors design by Perry et al. (2011) to manipulate participants' involvement in gameplay from passive observer to active player. In this way, we could test for the concomitant occurrences of the oscillatory activity that marks neural mirroring and inferential processing.
- To determine how sensorimotor information processing is affected by action inference, we used electroencephalography (EEG), to measure changes in alpha and theta frequency power and multiscale entropy of the sensorimotor signal and constructed a network graph to measure changes to information communication, during action observation.
- The RPS task has four conditions: 1) **No Context**: Participants watch two players play RPS 2) **Game**: Participants now count how many times one player wins 3) **Imagine**: Participants imagine playing against the computer but without making a physical movement and 4) **Play:** Participants play while making a physical move.
- Theta synchronization was measured as the change in theta (4–8 Hz) from a non-biological motion baseline at the Fz electrode. Mu suppression was measured in the alpha band (8–13 Hz) at the C3 electrode.
- To determine the temporal sequence for the occurrence of neural mirroring and action inference we calculated EEG microstates using the k means clustering method in EEGLAB.

TASK

Participant makes move 2000ms

Opponent makes move 2000ms

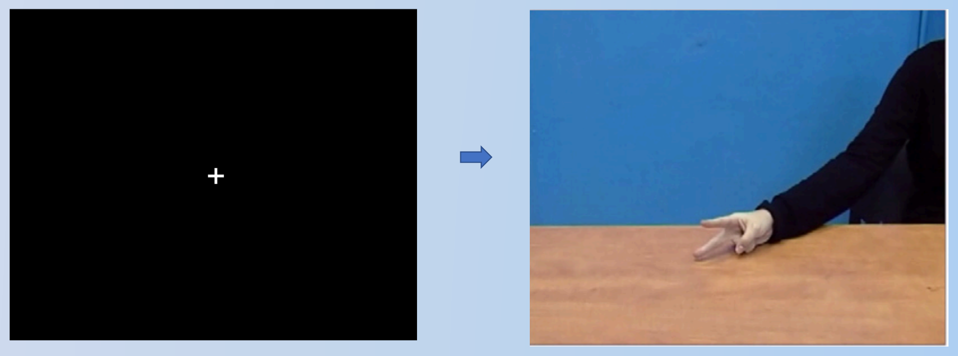


Figure1. Physical motion begins at 0 ms and completes at 1000 ms.

MU SUPPRESSION AND THETA SYNCH

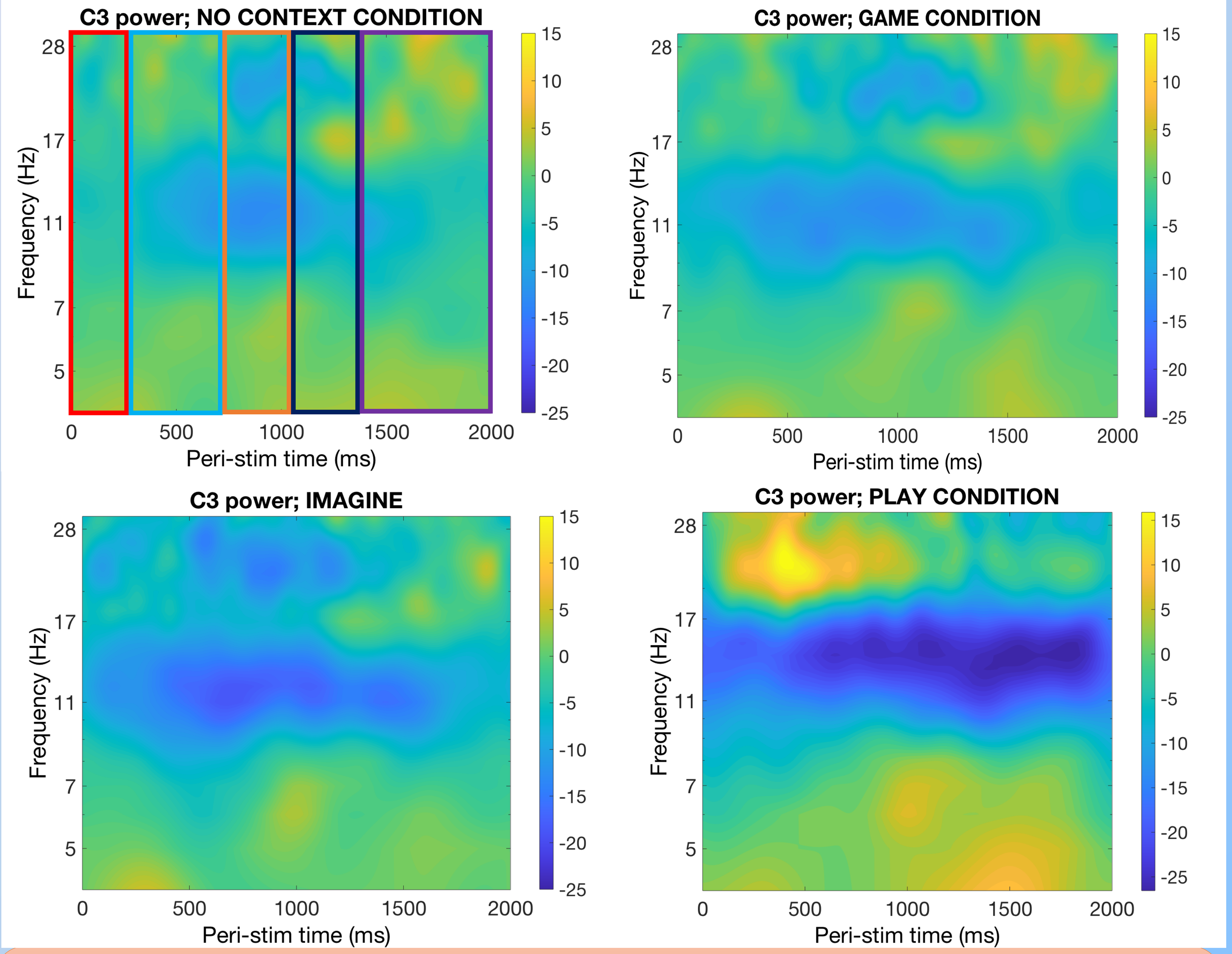
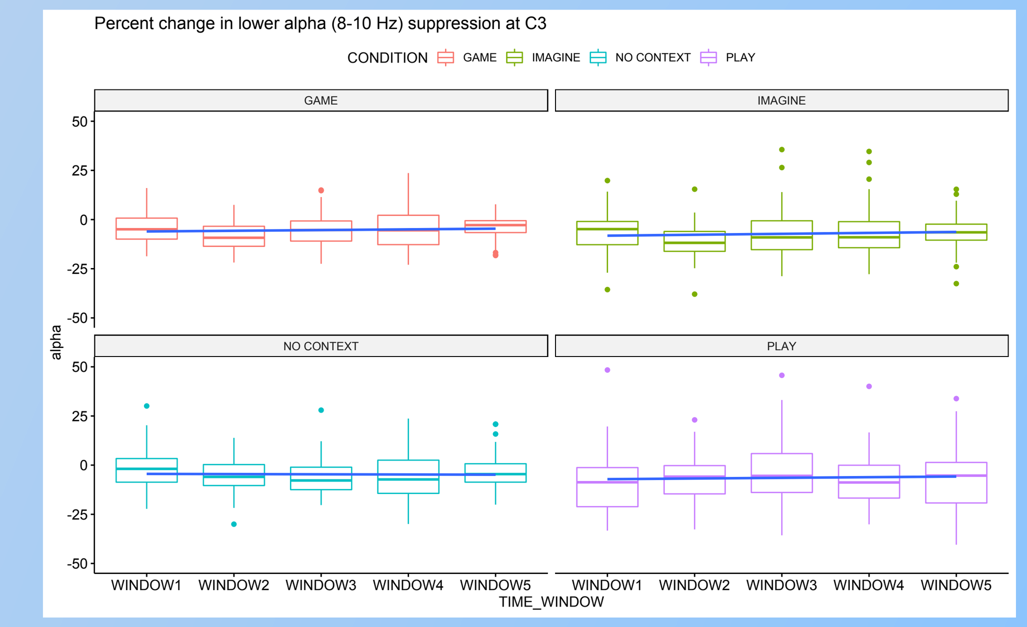
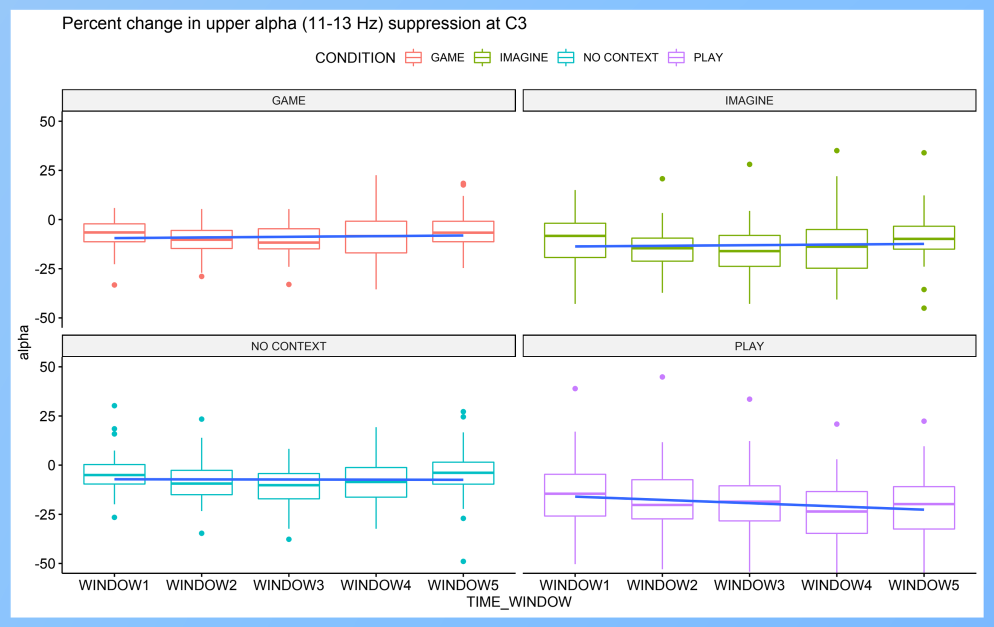
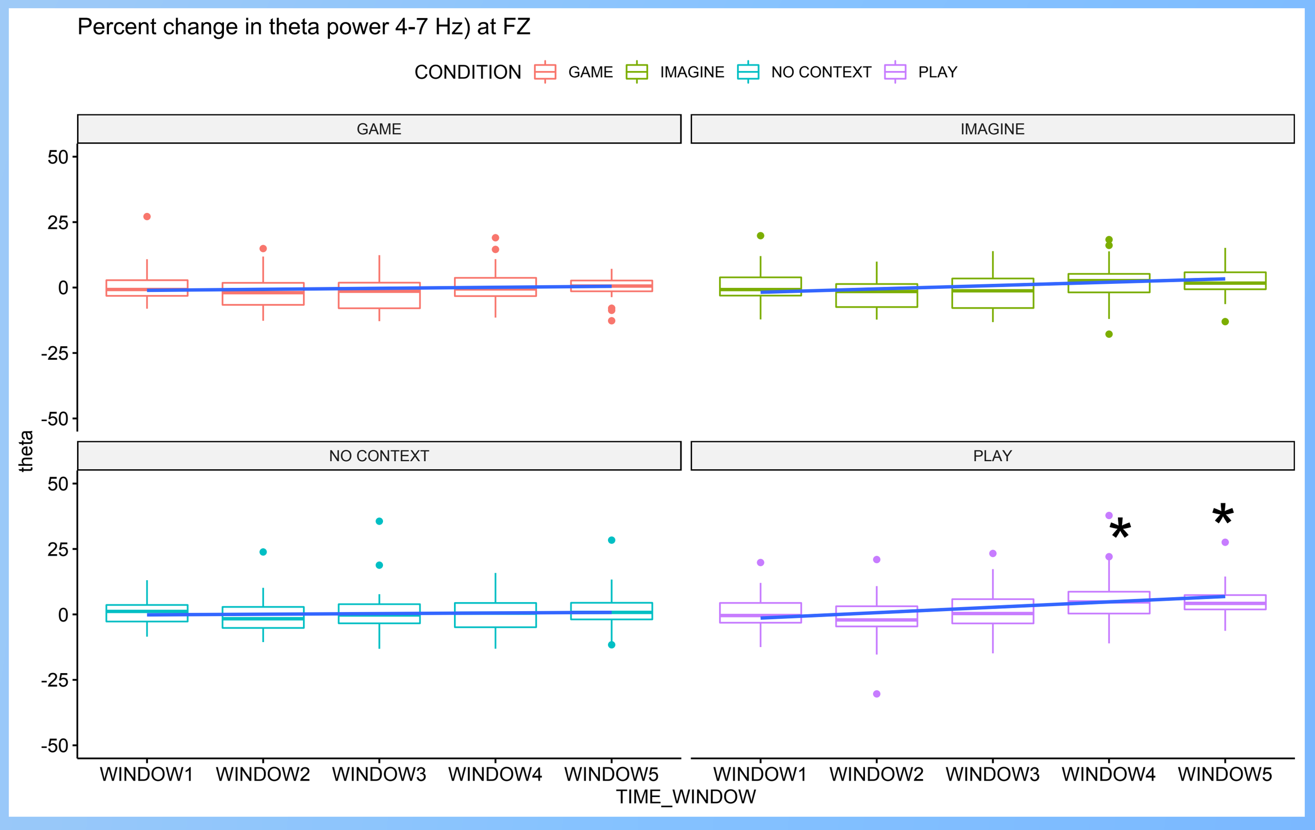


Figure 2. Color blocks indicate the duration for each microstate. Z axis shows % Change in power from non-biological motion baseline. Shows significant significant suppression in all conditions, NOCONTEXT (t*(42)=-4.922, p<0.001, d=0.759*), GAME (t*(41)=-8.797, p<0.001, d=1.374*), IMAGINE (t*(42)=-7.712, p<0.001, d=1.189*), PLAY (t*(41)=-3.069, p=0.004, d=0.479*).
Only the PLAY condition had significant theta synchronization t(41)=3.003, p=0.005, d=0.469), while all other conditions were not significant.

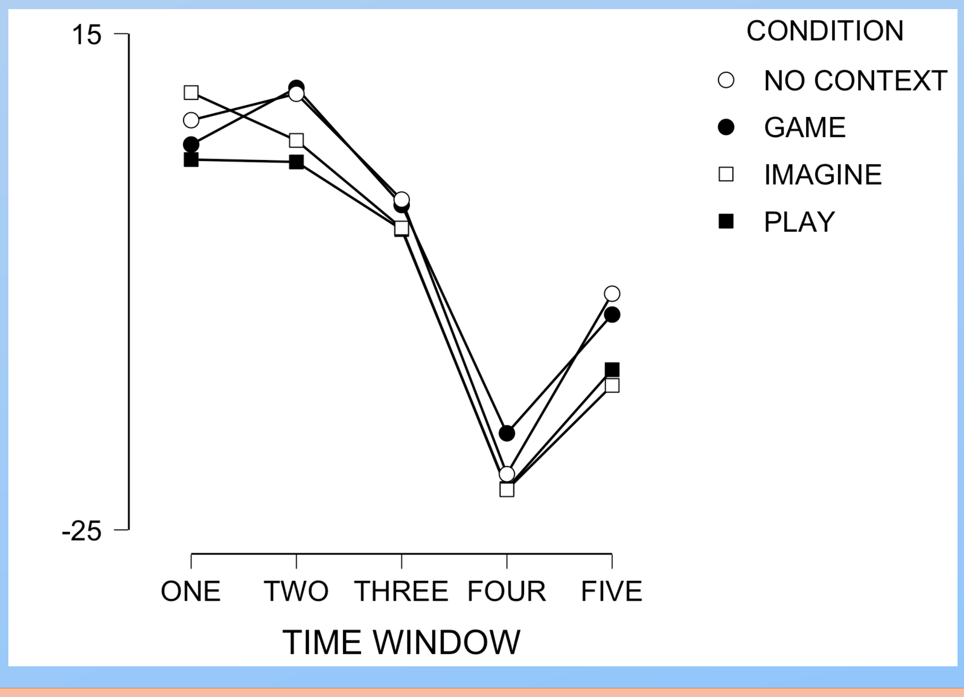






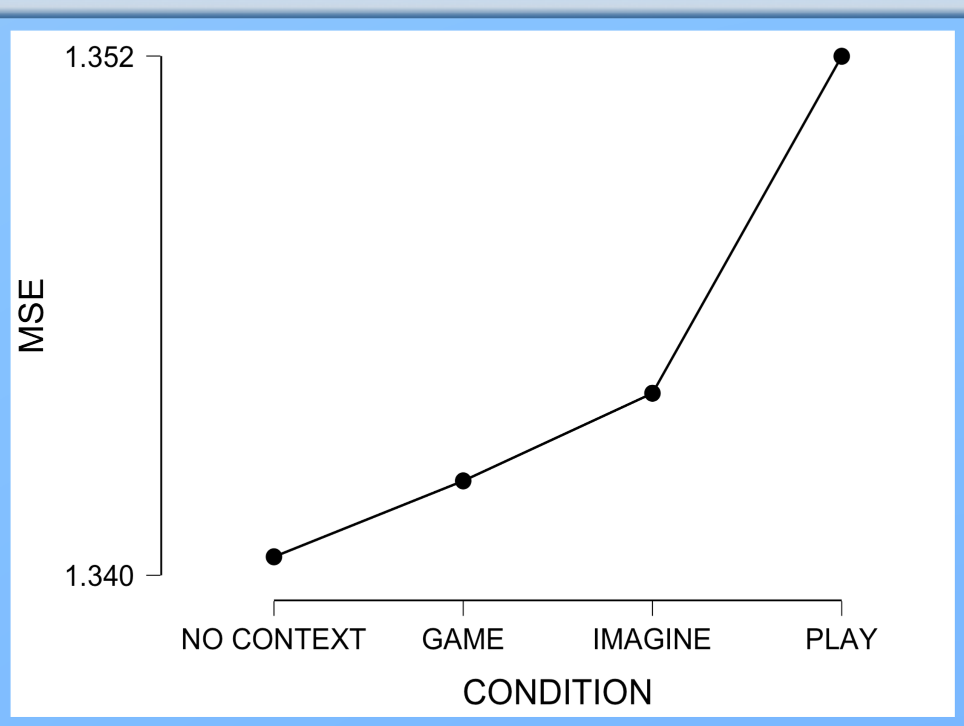
* = p<0.001

Alpha Network Efficiency



We confirmed significant global efficiency change using a series of one sample t-tests for each condition NOCONTEXT (t*(42)=-9.775, p<0.001, d=1.508*), GAME (t*(41)=-10.254, p<0.001, d=1.601*), IMAGINE (t*(42)=-11.835, p<0.001, d=1.826*), PLAY (t*(41)=-12.547, p=0.004, d= 1.959*)

MSE by Level of Involvement



We confirmed significant MSE change using a series of one sample t-tests for each condition NOCONTEXT (t*(42)=2.102, p=0.042, d=0.324*), GAME (t*(41)=2.159, p=0.037, d=0.337*), IMAGINE (t*(42)=-2.840, p=0.007, d=0.438*), PLAY (t*(41)3.447, p=0.001, d=0.538*). These results confirm a linear increase in entropy relative to baseline, across involvement conditions.

Discussion

- These findings seem to suggest that SMR does contribute information to the process of action inference. The changes were more specific to the upper alpha band, a possible indicator of cognitive processing. Theta synchronization was also specific to the PLAY condition only and became active following mu suppression.
- The role of the human mirror system in inferring action intention may indeed be to act as a gatekeeper in determining whether additional information is needed to determine an action's intent.

References

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