

# Different pathway-specific theta frameworks coexist in the hippocampus and are coordinated during exploratory and memory-guided behaviors



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## INTRODUCTION & METHODS

Hippocampal firing is organized in theta sequences controlled by internal memory-related processing (CA3-driven input) and by external sensory cues (EC-driven input) [1]. These computations are proposed to be coordinated in gamma oscillations segregated in the phase of the CA1 theta rhythm [2]. However, theta oscillations originating in different anatomical layers of the hippocampus are known to coexist [3] and, therefore, theta-gamma organization needs to be interpreted in the context of multiple rhythm generators.

## How these multiple theta rhythm generators and pathway-specific gamma oscillations interact?



LFP recordings

Inter-Cycle Phase Clustering (ICPC) index

CSD and ICA analysis

## PATHWAY-SPECIFIC THETA AND GAMMA OSCILLATIONS COEXIST IN THE HIPPOCAMPUS

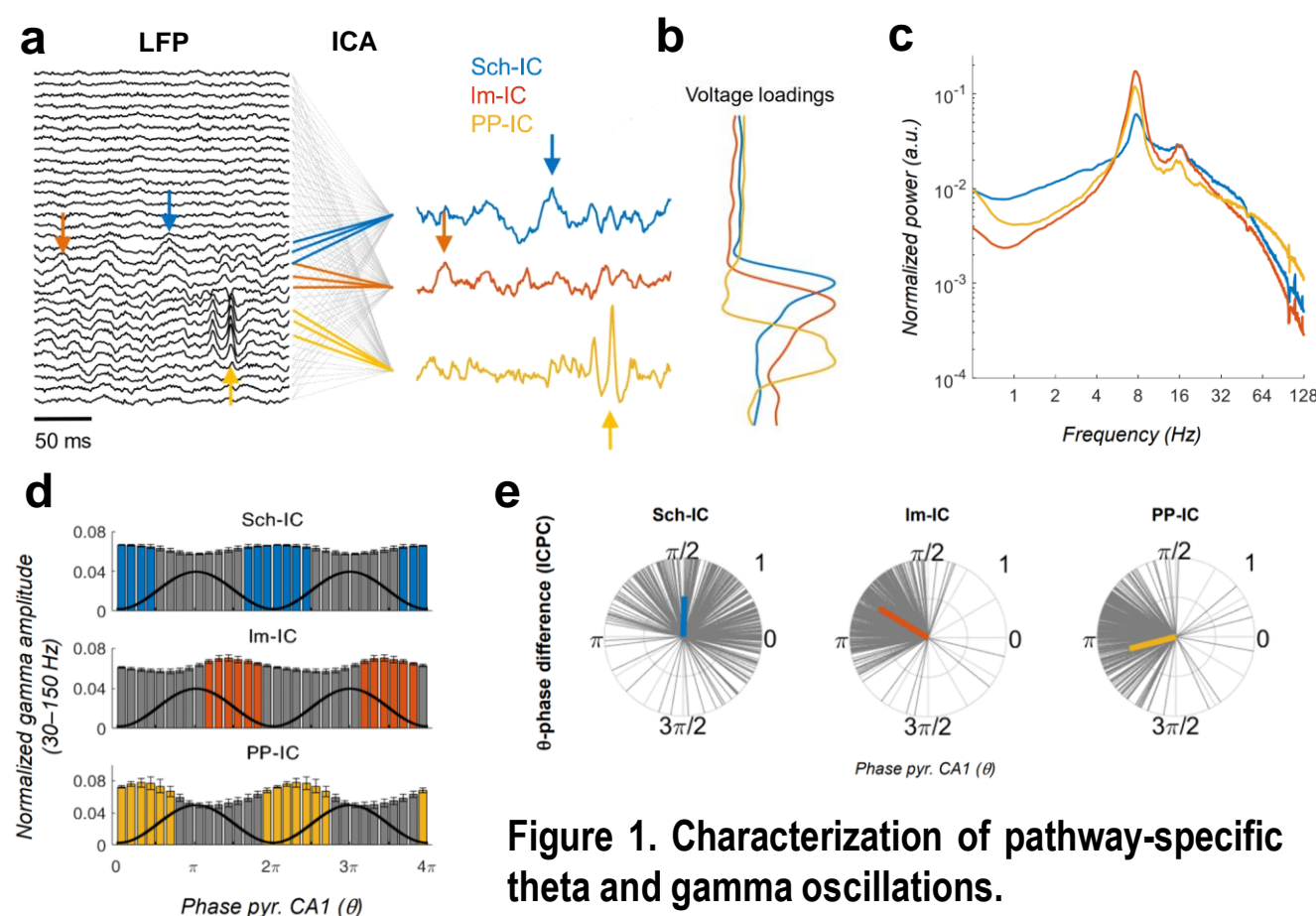


Figure 1. Characterization of pathway-specific theta and gamma oscillations.

## THETA GENERATORS ARE INDEPENDENT AND SHOW VARIABLE SYNCHRONY

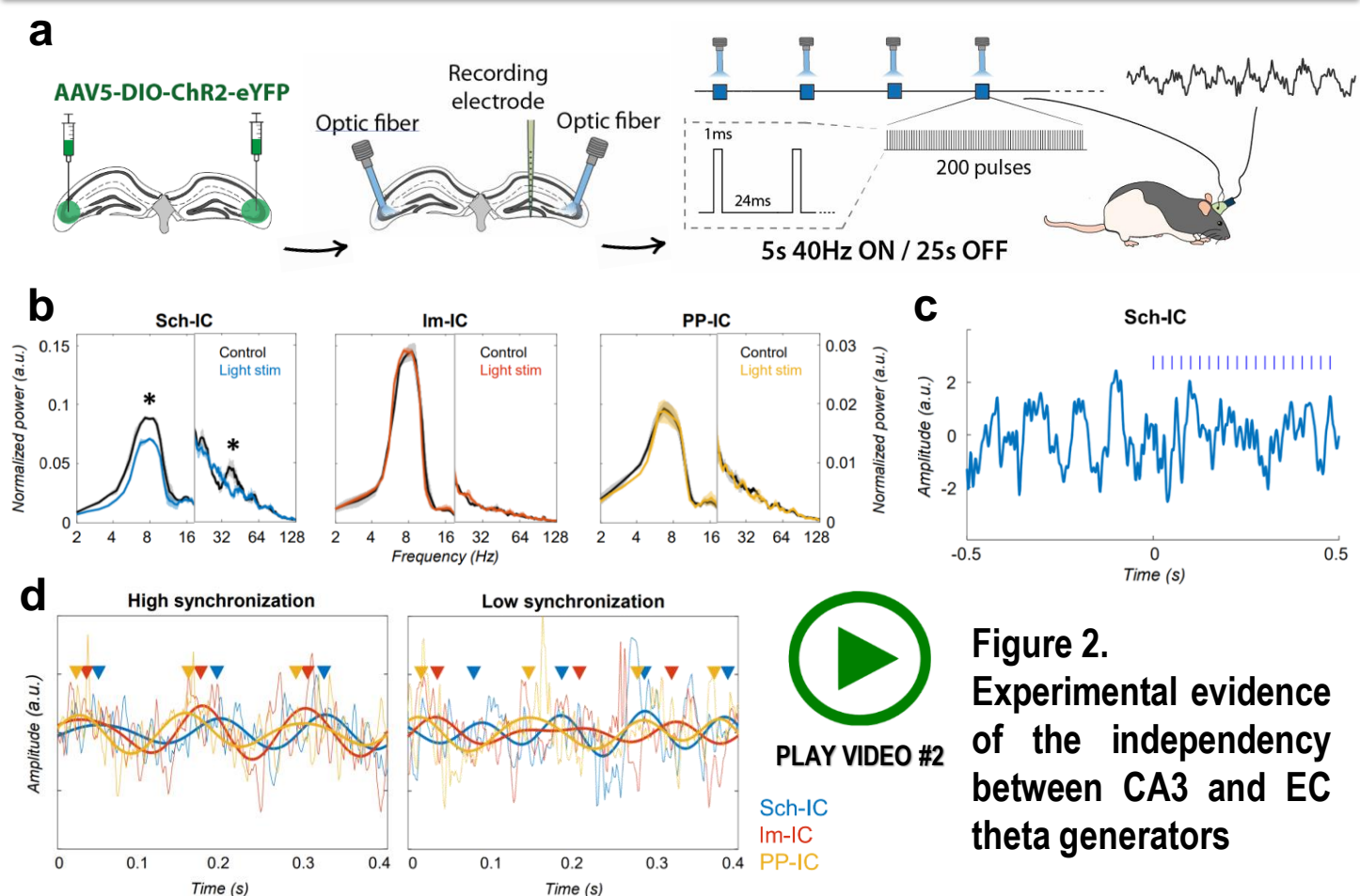


Figure 2. Experimental evidence of the independency between CA3 and EC theta generators

## THETA-GAMMA CFC IS PATHWAY-SPECIFIC AND IS ASSOCIATED TO THE SYNCHRONIZATION BETWEEN PATHWAYS

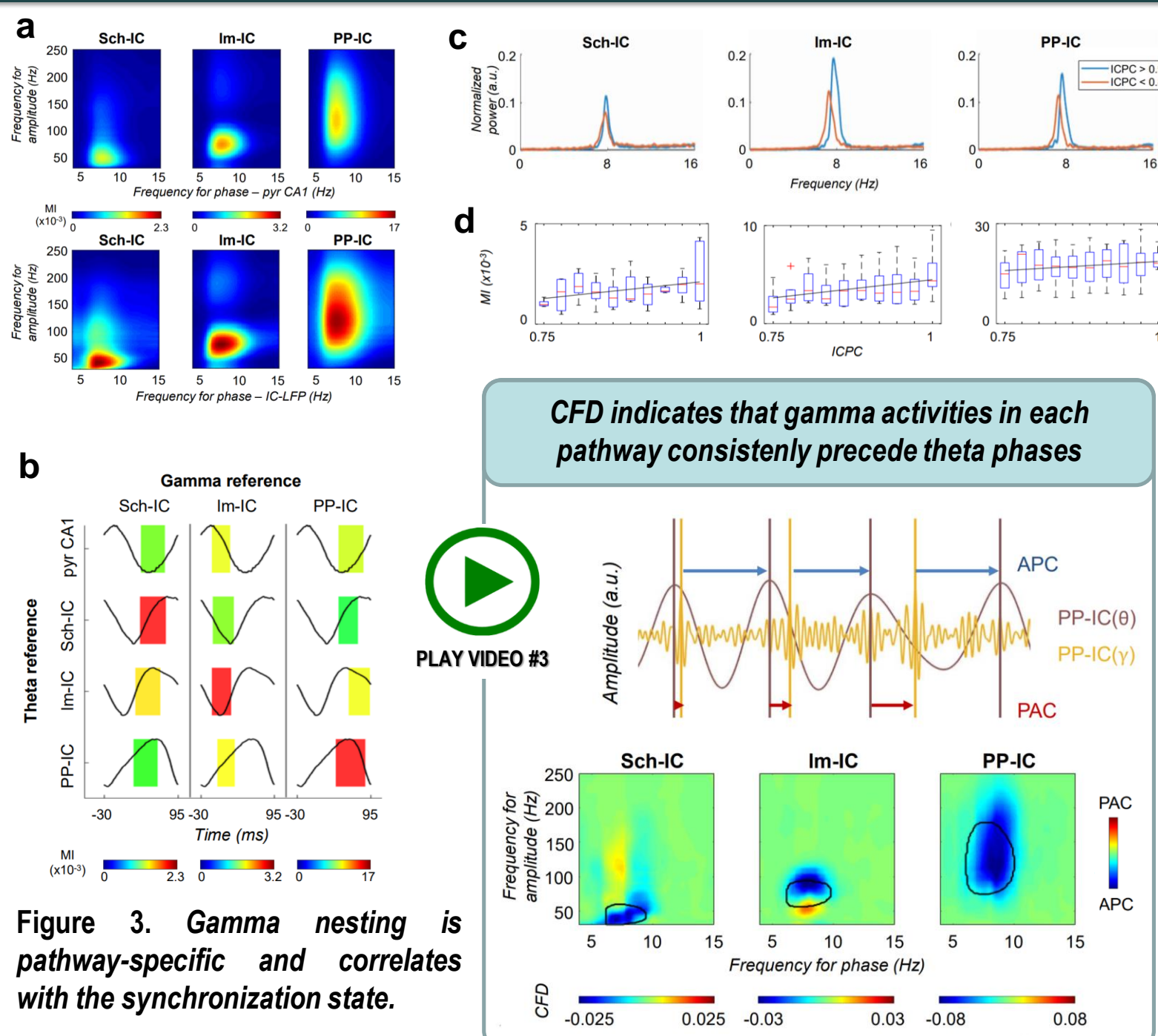
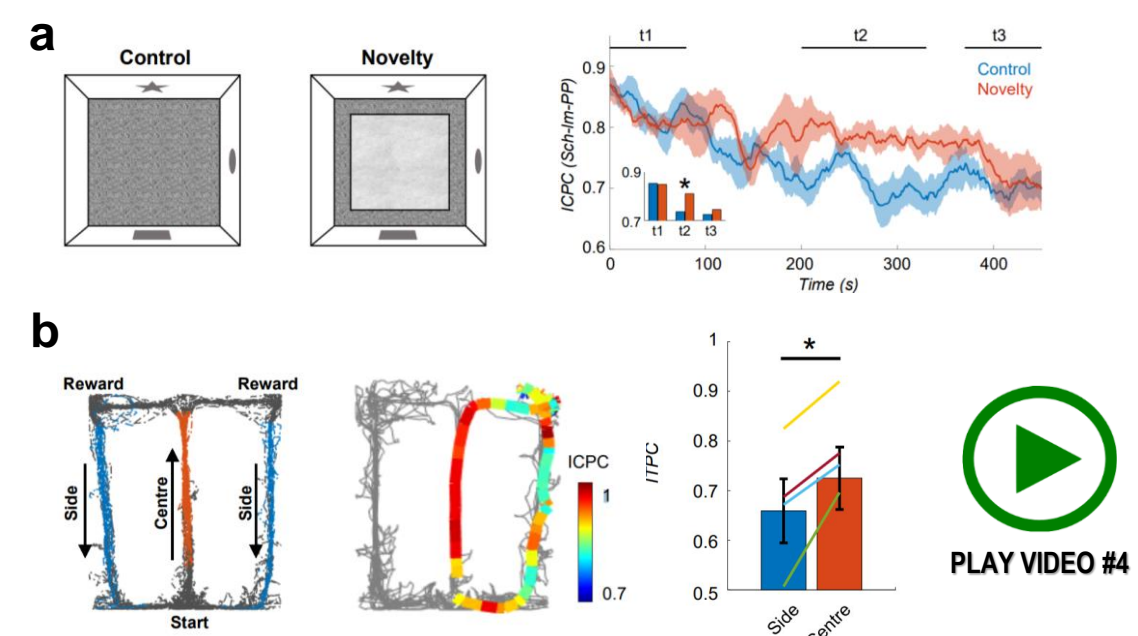


Figure 3. Gamma nesting is pathway-specific and correlates with the synchronization state.

## BEHAVIOURAL MODULATION OF CFC AND THETA SYNCHRONIZATION

Figure 4. Maximum synchronization between theta rhythms occurs during mismatch novelty and memory-guided exploration.



## CONCLUSIONS

- ✓ In the present work we provide conclusive evidence supporting independent theta oscillations in the hippocampus.
- ✓ We show that phase locking between theta generators is associated with stronger theta-gamma CFC. Directionality analysis demonstrates that band-specific gamma activities consistently precede theta waves, suggesting a gamma → theta mechanism of theta synchronization.
- ✓ Based on these results we propose a mechanism of parallel processing in the hippocampus with capacity to segregate or integrate computations based on the coexistence of different theta-gamma frameworks that flexibly couple or decouple accommodating the cognitive needs.

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[1] Siegle and Wilson, *eLife*, 2014 [2] Colgin et al., *Neuron*, 2009 [3] Buzsáki, *Neuron*, 2002