Quality vs quantity of consciousness: empirical evidence from integrated information analysis of human intracranial data

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1. Background

Integrated Information Theory (IIT) attempts to elucidate the link between consciousness and its neural basis through its informational structure. (Oizumi et al 2014 PLoS Comp Biol)
More specifically, the theory gives quantitative predictions about the relationship between consciousness and informational structure.

○ Quality of consciousness (e.g. seeing face) correlates with "shape" of Integrated Information Structure (IIS); and
○ Quantity of consciousness (e.g. sleep vs. awake) correlates with "volume" of IIS (precisely System-level II or big phi).
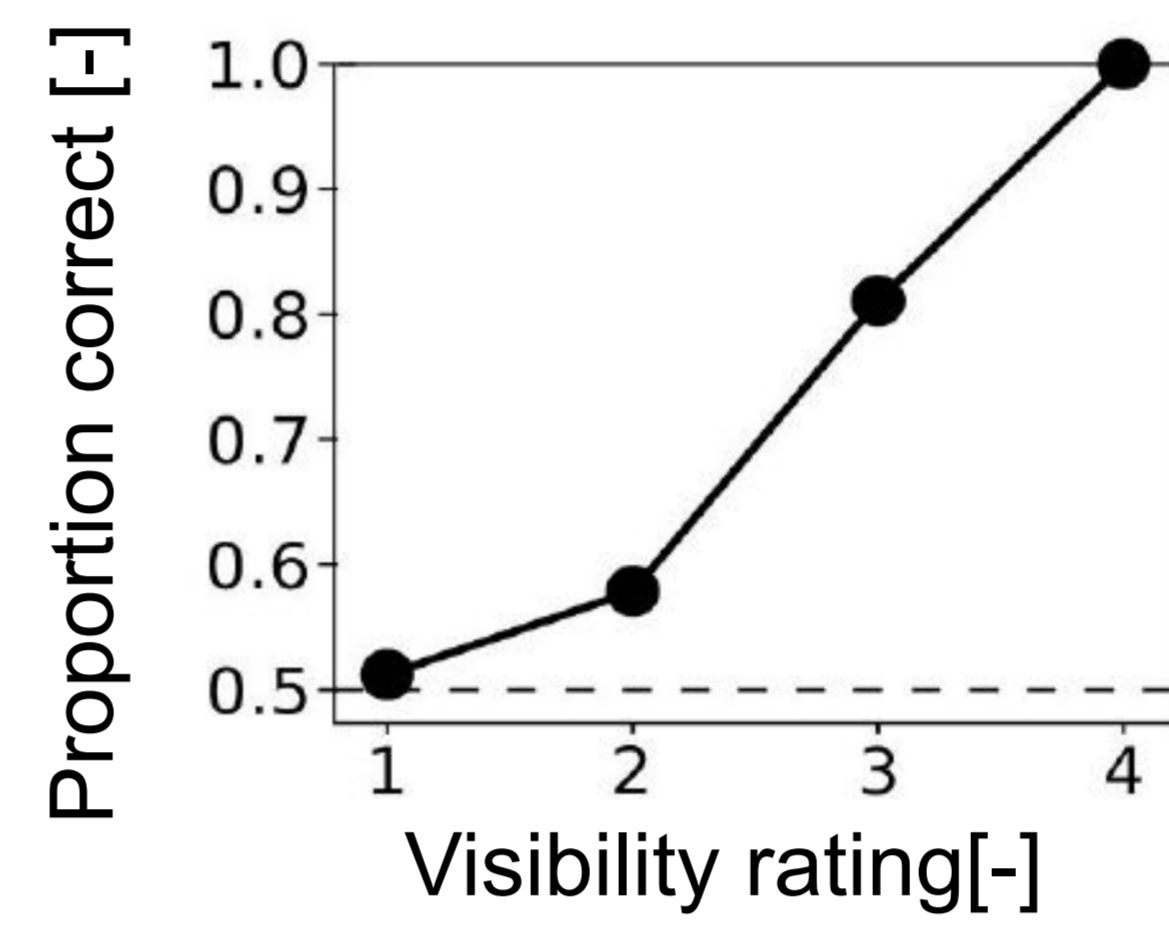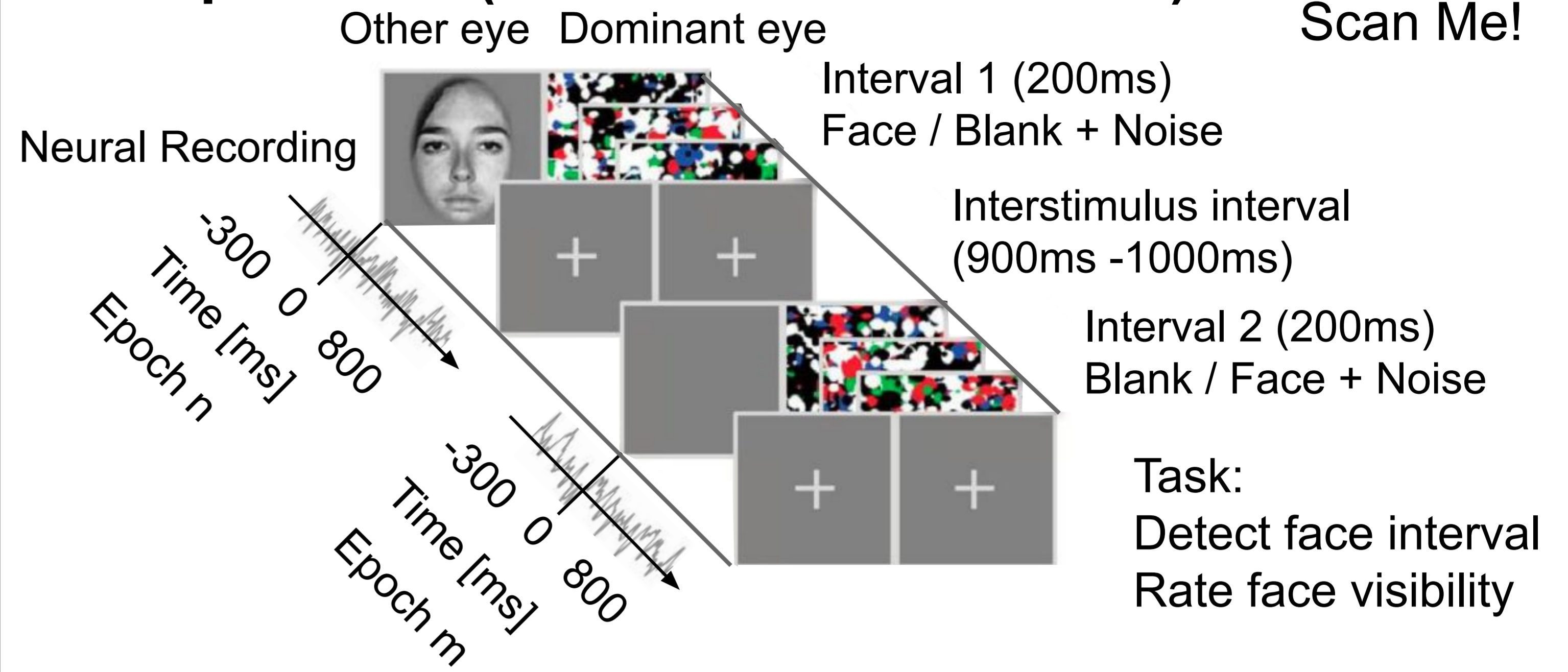
In addition, the theory gives a operationalisation of informational structure based on neural system.

○ Both IIS and System-level II are computed from neural activity based on causal connections of the neural system.

Then, we test that

H1 "Shape" of IIS from neural recording correlates with quality of consciousness.

H2 "Volume" of IIS from neural recording does not correlate with quality of consciousness.

2. Experiment (Haun et al 2017 eNeuro)

Other eye Dominant eye
Neural Recording
Interval 1 (200ms) Face / Blank + Noise
Interstimulus interval (900ms -1000ms)
Interval 2 (200ms) Blank / Face + Noise
Task: Detect face interval Rate face visibility

○ Visibility = 4 or 3 Subject perceived face.

○ Visibility = 2 or 1, Blank Interval Subject perceived noise.

3. Compute Integrated Information (II)

a. Channel Location

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R ✛ L
Post.

b. Binarisation of Local Field Potential
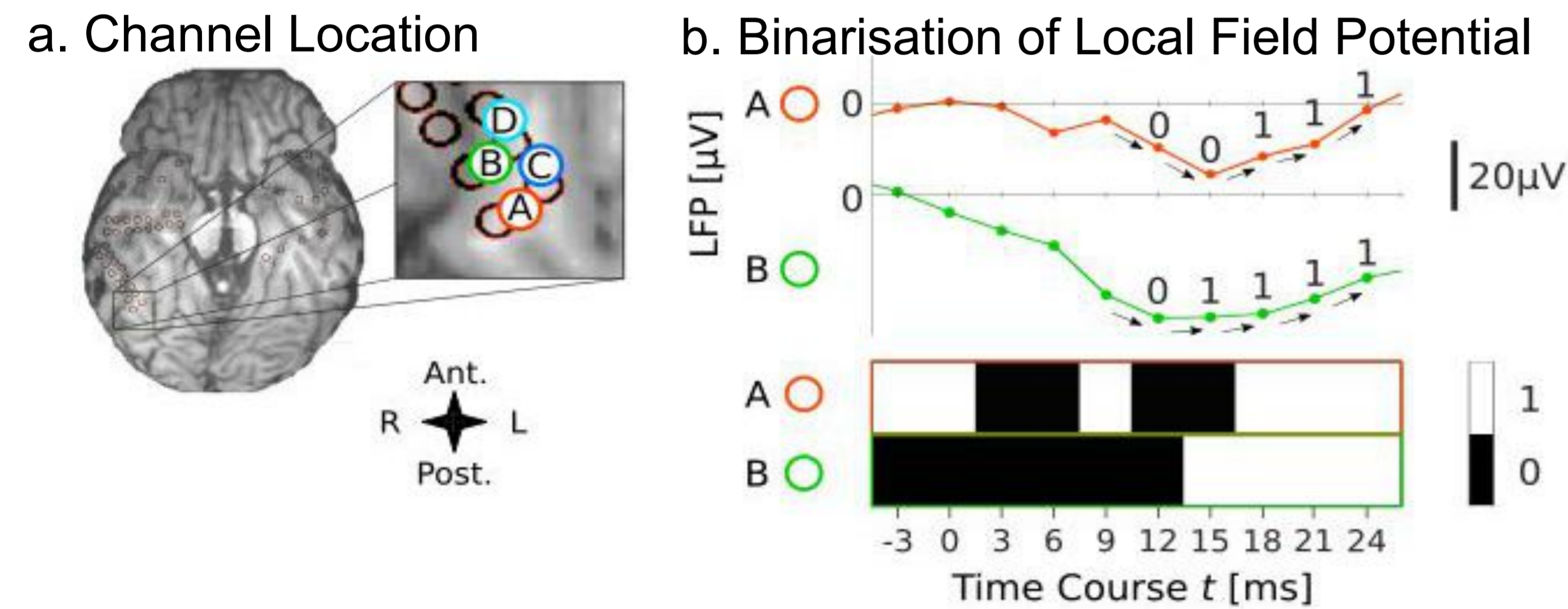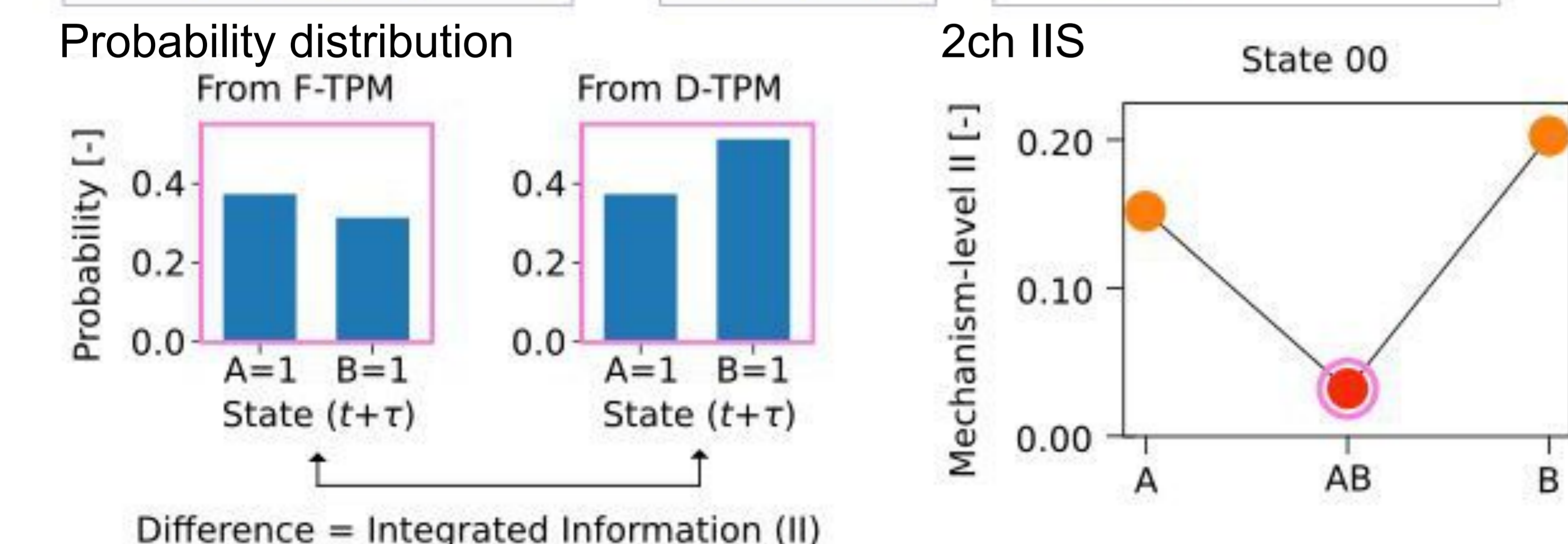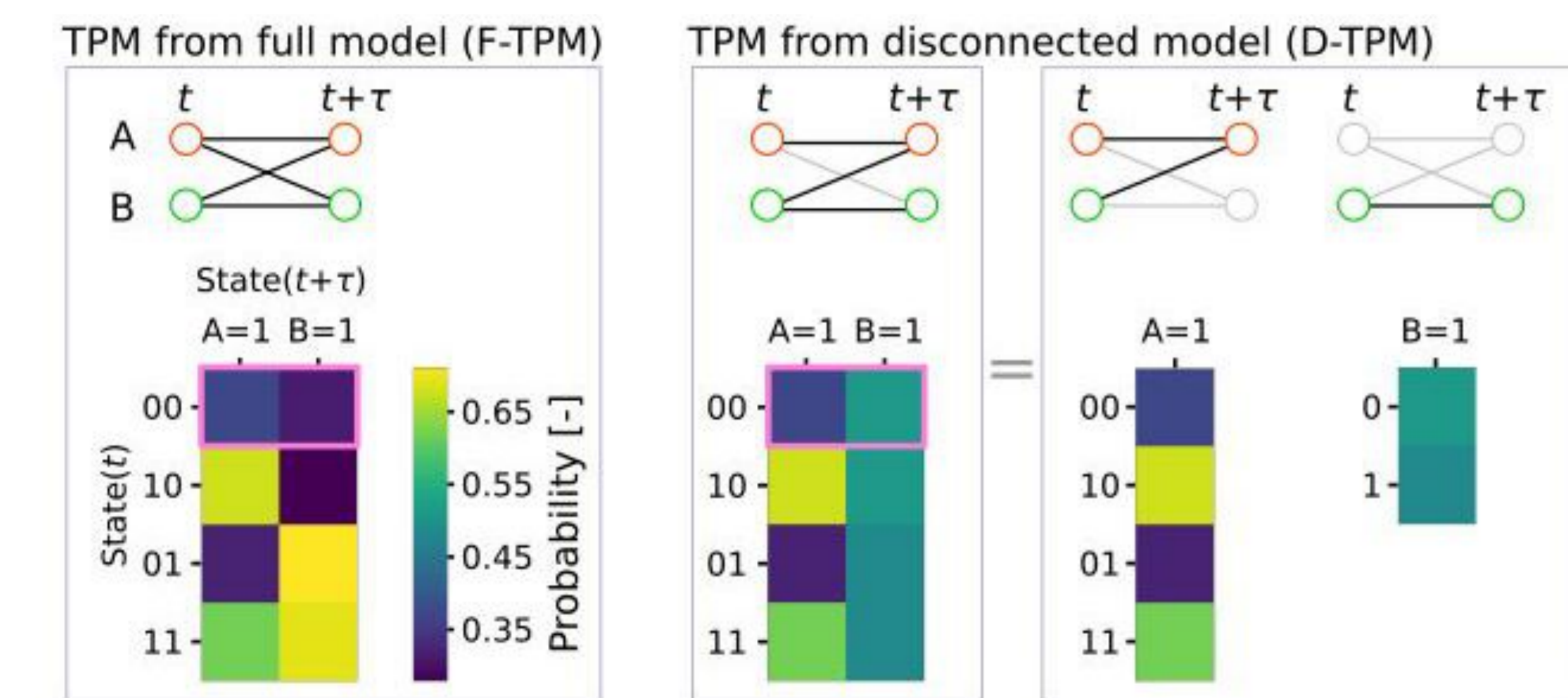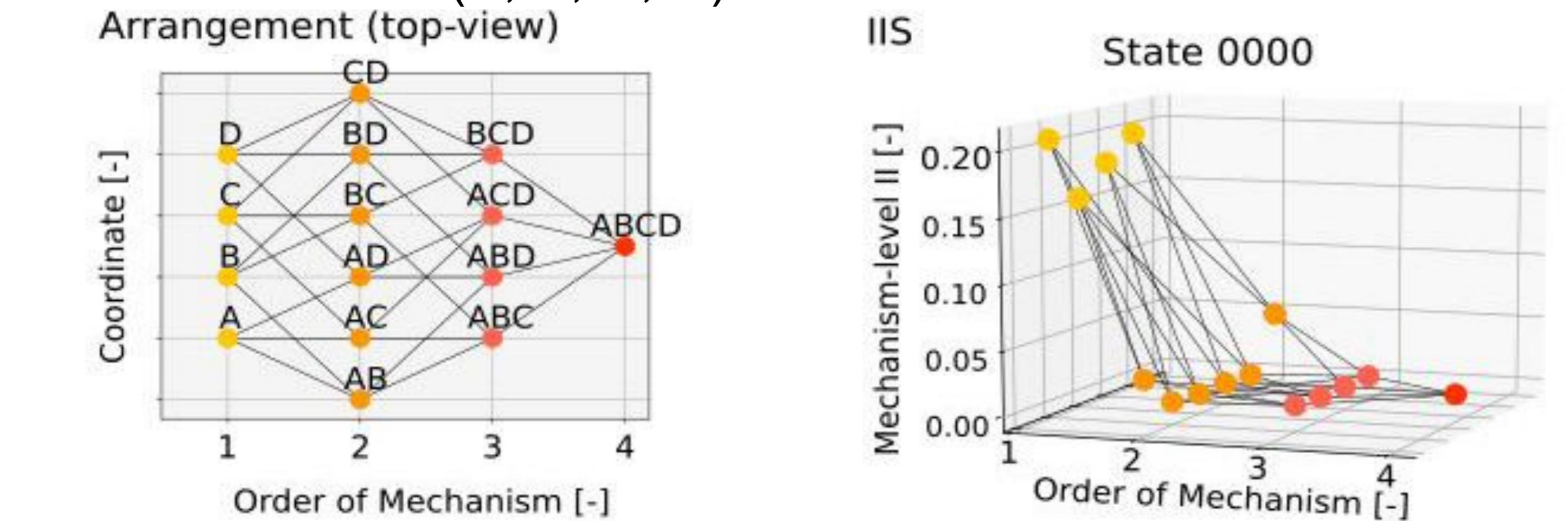

c. Explanation of Integrated Information (II) with 2 ch (A, B)

2ch System integratively generates information (generates II)?

Information
○ How much can current state affect future state and can be affected by past state?
○ Determined by causal connections between A and B

TPM (Transition Probability Matrix)
○ Probability of state transition from current to future
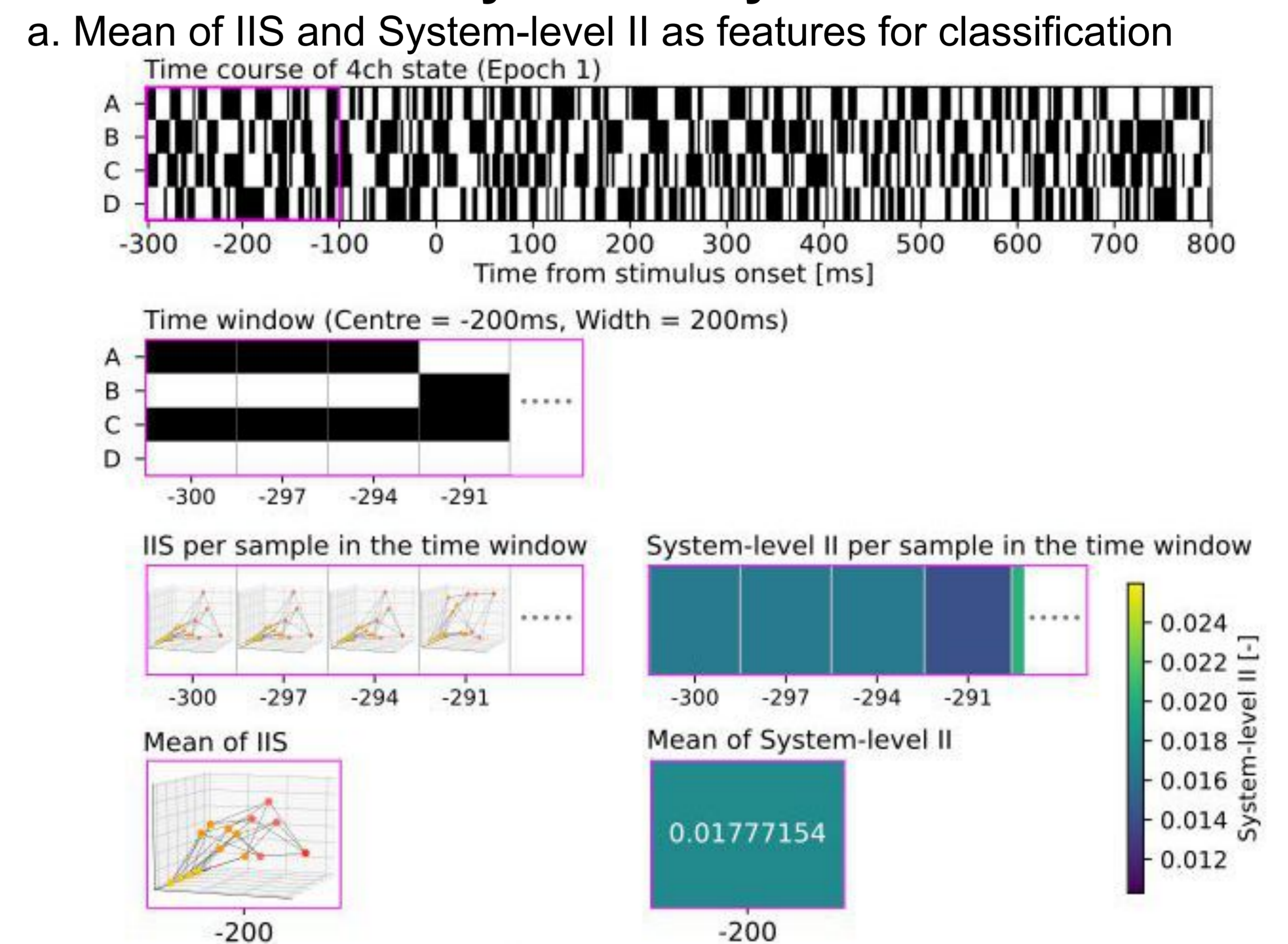○ Characterises causal connections between A and B

II
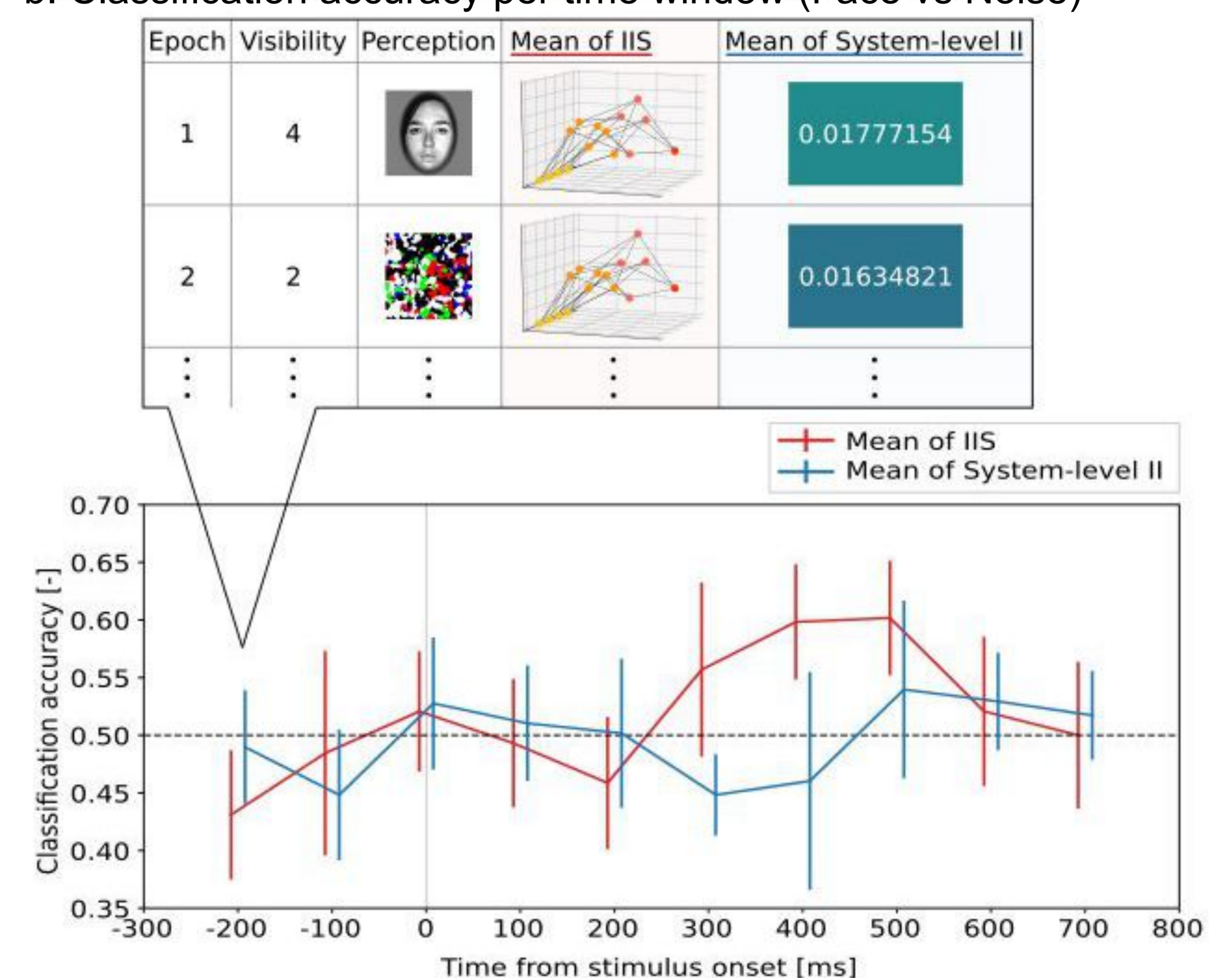○ How much does information change after ignoring some causal connections?

TPM from full model (F-TPM)
TPM from disconnected model (D-TPM)

Probability distribution
From F-TPM
From D-TPM
Difference = Integrated Information (II)

2ch IIS
State 00

d. IIS from 4 ch (A, B, C, D)

Arrangement (top-view)
IIS
State 0000

4. Classification by IIS and system-level II

a. Mean of IIS and System-level II as features for classification

Time course of 4ch state (Epoch 1)
Time window (Centre = -200ms, Width = 200ms)
IIS per sample in the time window
System-level II per sample in the time window
Mean of IIS
Mean of System-level II
0.01777154

b. Classification accuracy per time window (Face vs Noise)

Epoch	Visibility	Perception	Mean of IIS	Mean of System-level II
1	4	(face)		0.01777154
2	2	(noise)		0.01634821
⋮	⋮	⋮	⋮	⋮

Mean of IIS
Mean of System-level II

5. Summary

To H1 ("Shape" of IIS correlates with quality of consciousness.)
Partially supported: "Shape" of IIS is able to classify face vs noise perception above chance 300-500ms after stimulus onset.

To H2 ("Volume" of IIS does not correlate with quality of consciousness.)
Supported: "Volume" of IIS (System-level II) is not able to classify face vs noise perception.