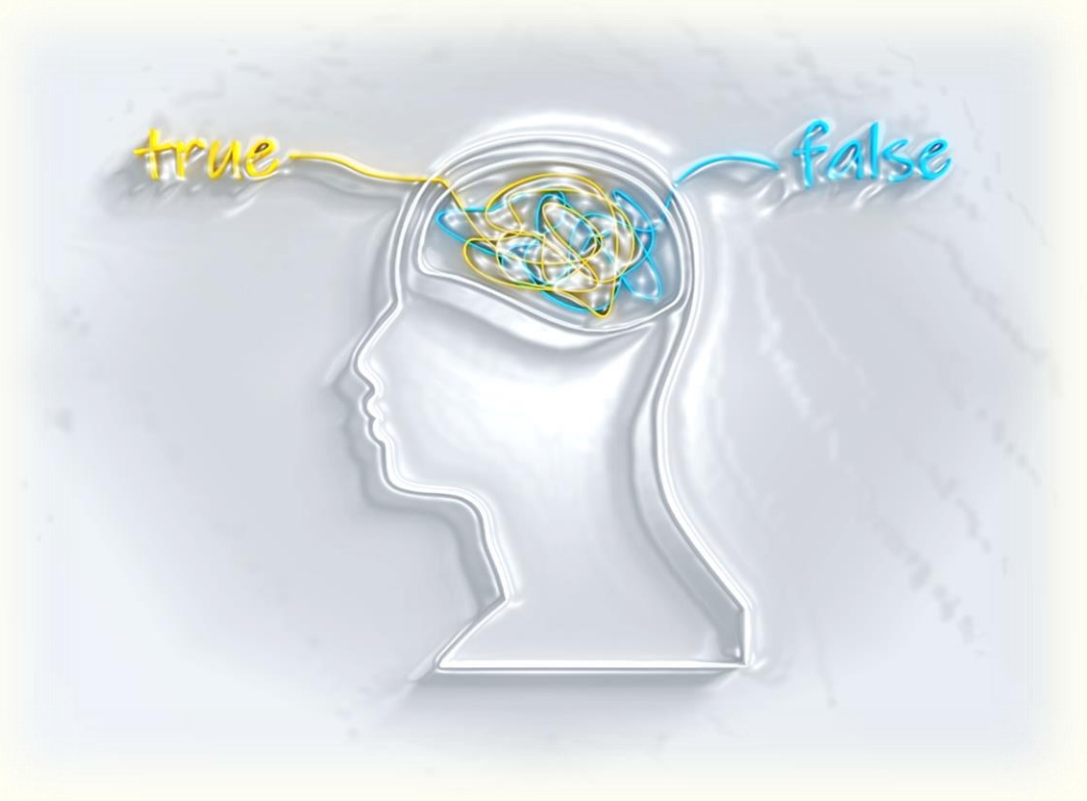


# PERSISTENT HOMOLOGY OF FALSE MEMORY

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2 July 2024  
Intensive Scientific Report Day

CCG Group, Department of Physics  
Shahid Beheshti University



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You can go in there and change it,  
but so can other people.

Elizabeth Loftus





# FALSE MEMORY

Mental experiences erroneously taken to be veridical portrayals of past occasions

# Memory

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## Theory

- The source monitoring framework
  - Mental experiences
  - Supporting memories
  - Knowledge
  - Beliefs
- Memory attributions
  - Motives
  - Goals
  - The social context

## Memory Gaps

- Reasons
  - Emotional involvement
  - Expectations
  - Environmental changes
  - Time between encoding and retrieval
- Common concepts of theories
  - Constructive processes of reconstruction
  - Item-specific versus communication processing
  - Extension of activation
  - Monitoring

# Autobiographical Advertisement Effect on Memory

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## Autobiographical Memory

- Communication networks
- Person's self-concept
- Influencing a person's behavior

## Advertisement

- Meaningful and personal association
- Childhood and past emotional attachments
- Semantic connection
- Pre and post goal emotions

# Methods to Investigate False Memory Formation

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- Impossible memories
- Implicit associative response (IAR)
- Deese, Roediger, and McDermott (DRM)
- Investigating behavioral tasks, fMRI, EEG and ERP



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# TOPOLOGICAL DATA ANALYSIS

Combination of statistical, computational, and topological methods allowing to find shape-like structures in data

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# TDA

- Complex multi-dimensional and noisy datasets
- Embedding Data to point clouds
- Simplicial complexes

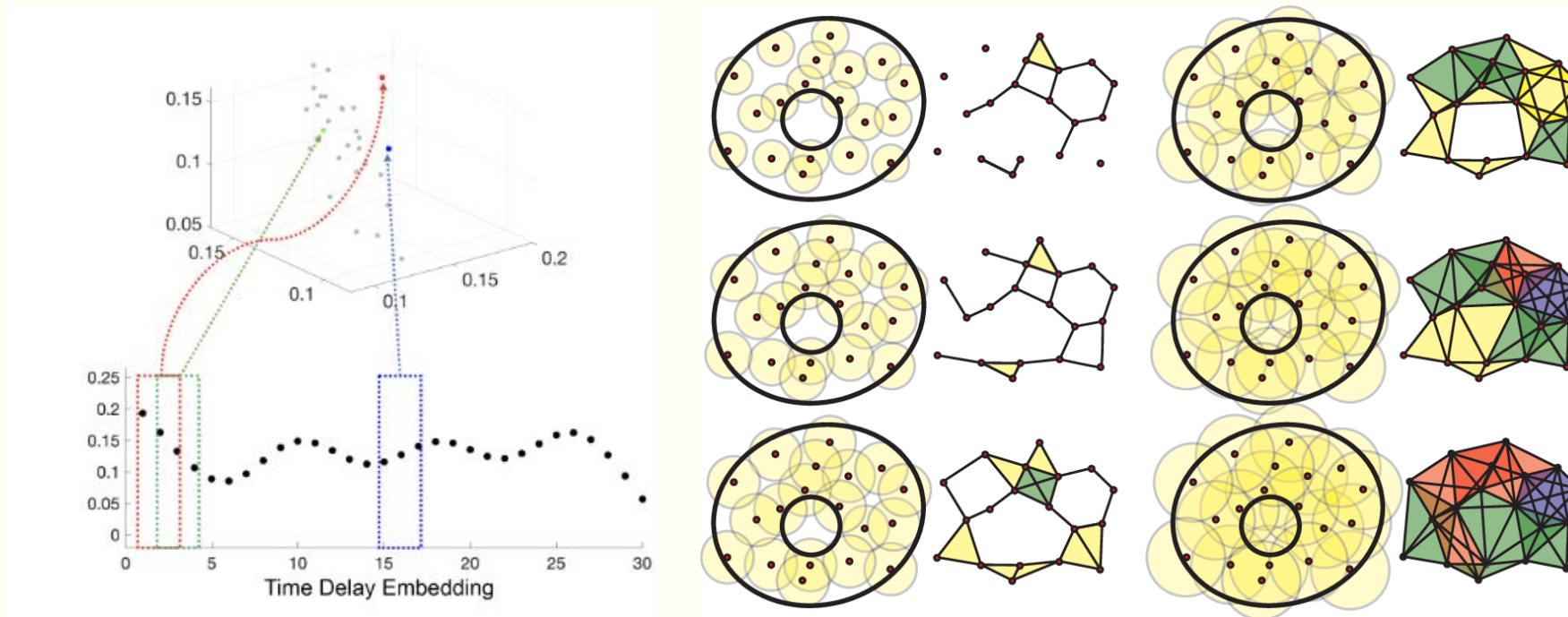


Fig. 3. left. time delay embedding of univariate time series. Das, S.; Ombao, H.; Chung, M. . 17 Oct 2022 . TOPOLOGICAL DATA ANALYSIS FOR FUNCTIONAL BRAIN NETWORKS . DOI  
Fig. 3. Ghrist, R. . 2007 . Barcodes: The persistent topology of data . URL



# Persistent Homology

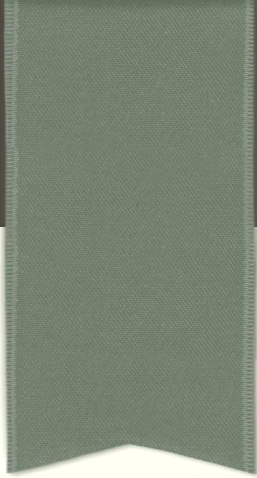
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## Representations

- Persistence diagrams
- Persistent landscape
- Betti curves
- Silhouette

## Features

- Amplitudes
- Persistence entropy
- Number of points
- Filtration params
- Areas under curves

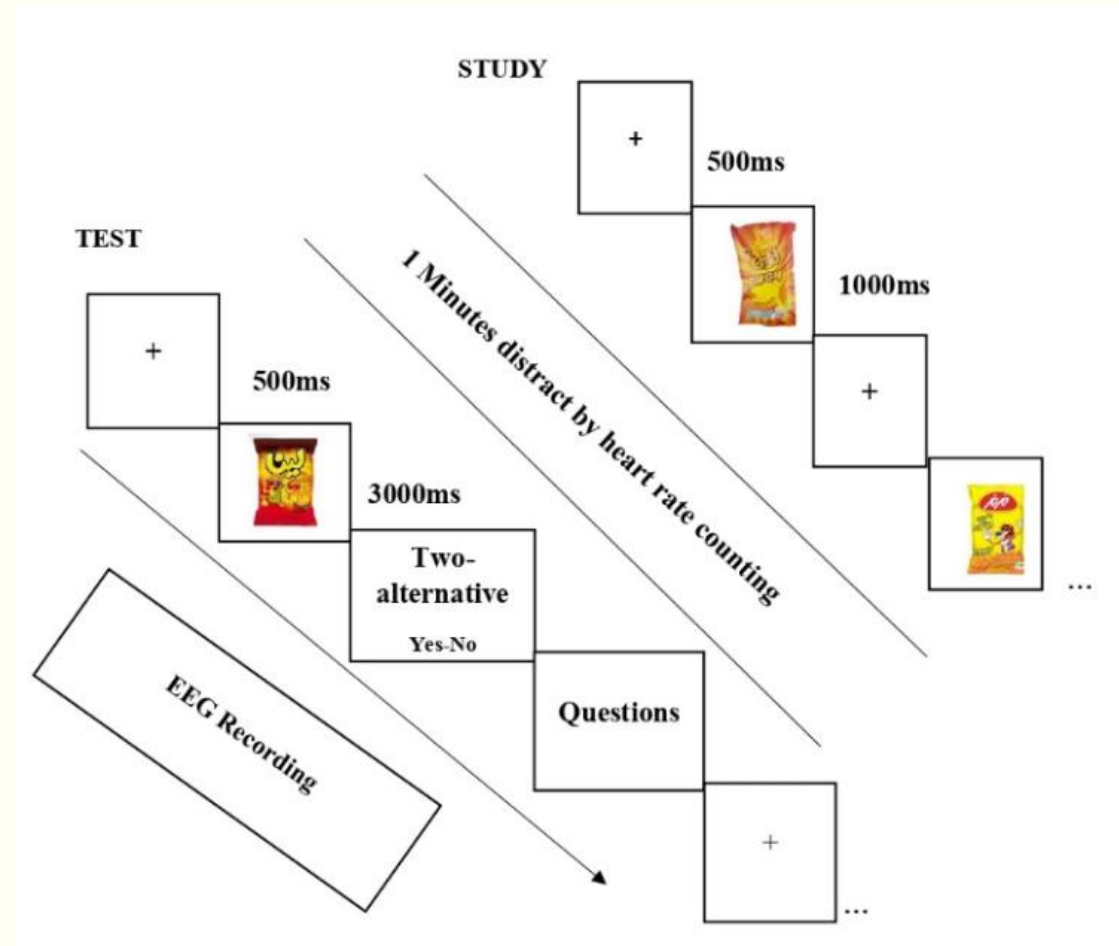


# DATA

Inducing false memories based on autobiographical brand images

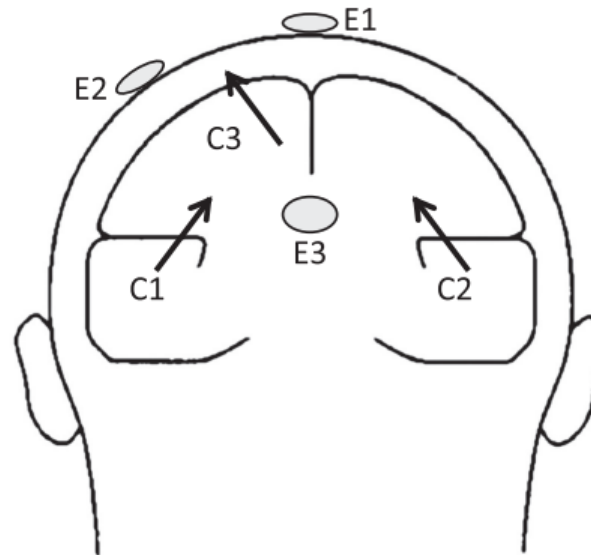
# Data

- 36 participants
- 31 EEG signals
- Exclusion criterion
- DRM paradigm
- Neutral images from IASP
- Brand images from Jarf Negar

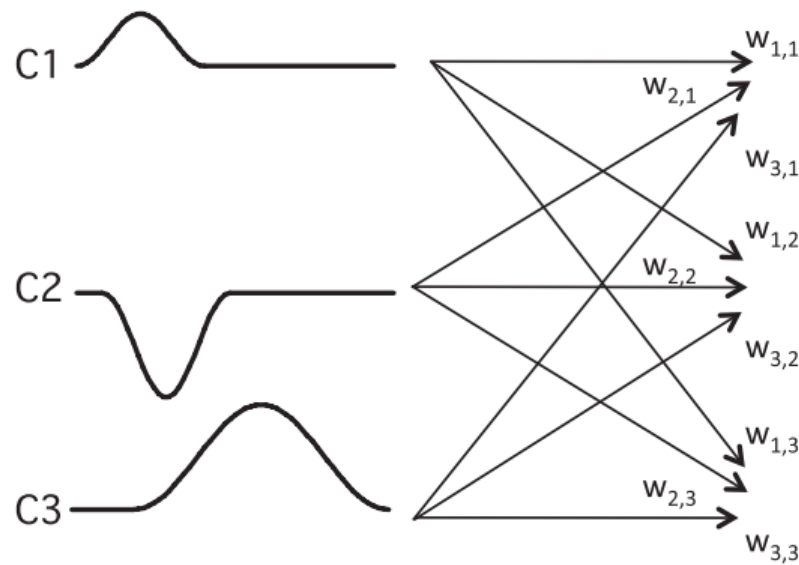


Hypothetical weights from components to electrodes

	Electrode 1	Electrode 2	Electrode 3
Component 1	$w_{1,1} = 1$	$w_{1,2} = 0.25$	$w_{1,3} = 0.5$
Component 2	$w_{2,1} = 0.5$	$w_{2,2} = 0.5$	$w_{2,3} = -0.5$
Component 3	$w_{3,1} = 1$	$w_{3,2} = 0.75$	$w_{3,3} = 0.5$



Source waveform at the generator location for each component



Observed waveform at each electrode site

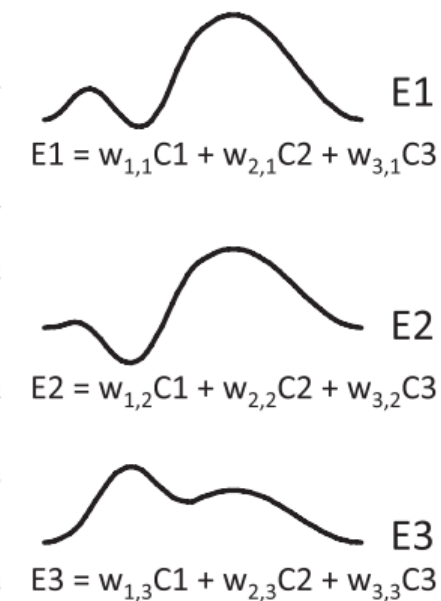


Fig 2.3 . Luck 2014 . Relation between the underlying component waveforms and the observed scalp waveforms. Book

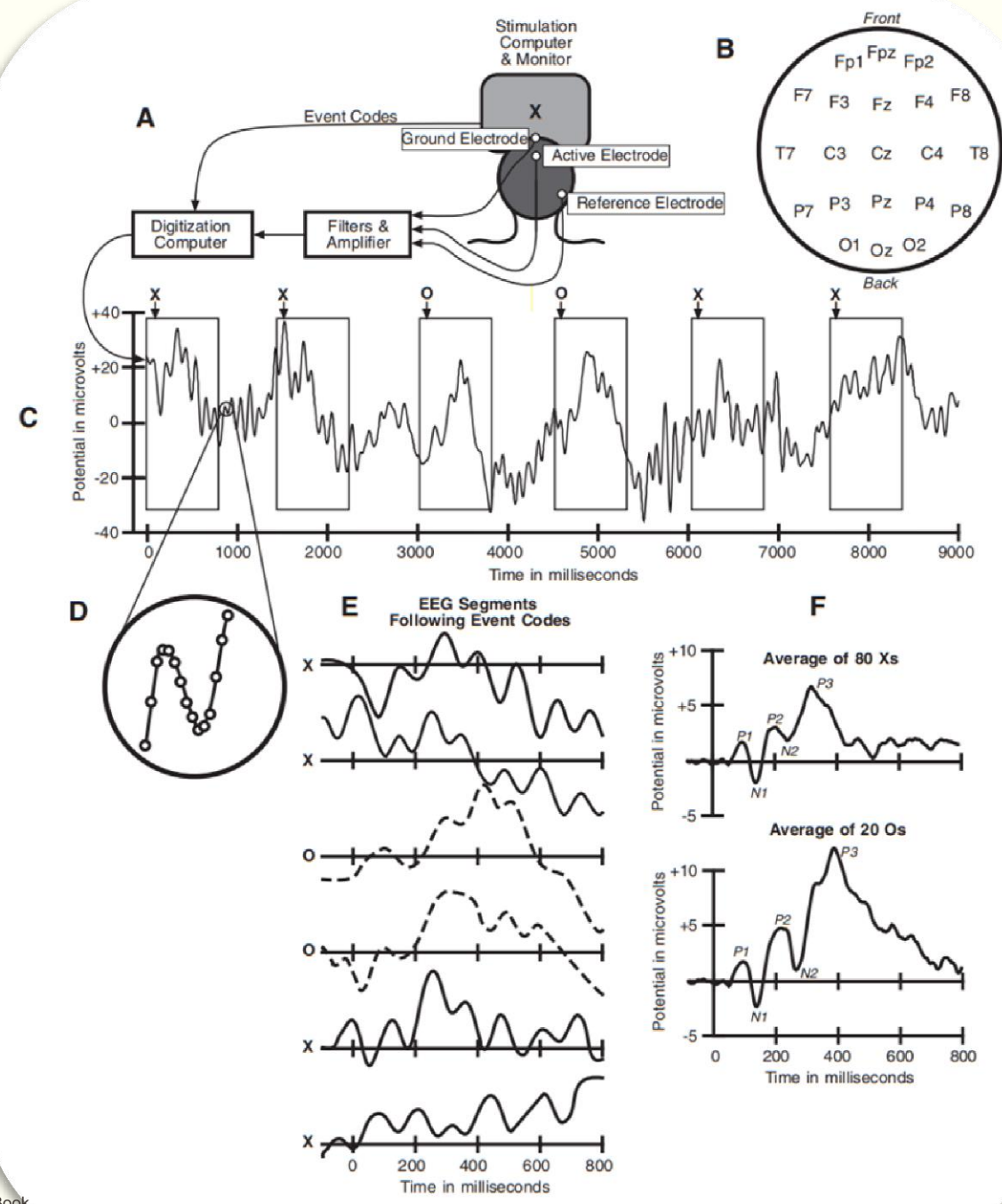


Fig 1.1 . Luck 2014 . Example ERP experiment using the oddball paradigm . Book

# Findings

- Autobiographical brand images can induce false memory
- Increased reaction time (RT)
- No gender difference in rate and RT
- More susceptibility in children
- P300
- Late positive component (LPC)
- FN400
- Males:  
'P4', 'C3', 'C4', 'F3', 'F4', 'Fp1', 'Fp2', 'F7', 'Fpz', 'Ft7', 'Fc4', 'Cp4'

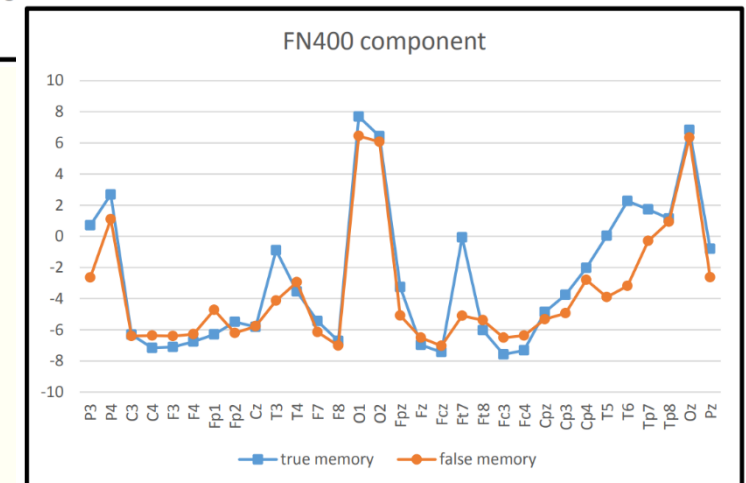
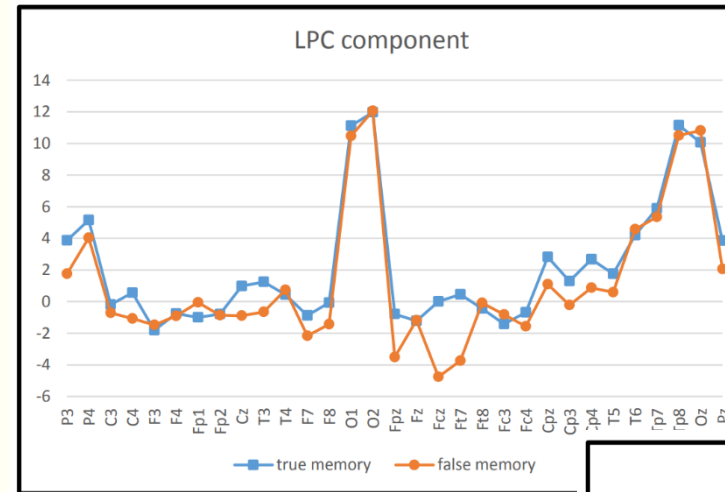


Fig. 4.9,11,13 . Shabani, M . Jan 2019 . Create a false memory based on your own life ads A letter with a growth attitude . Thesis

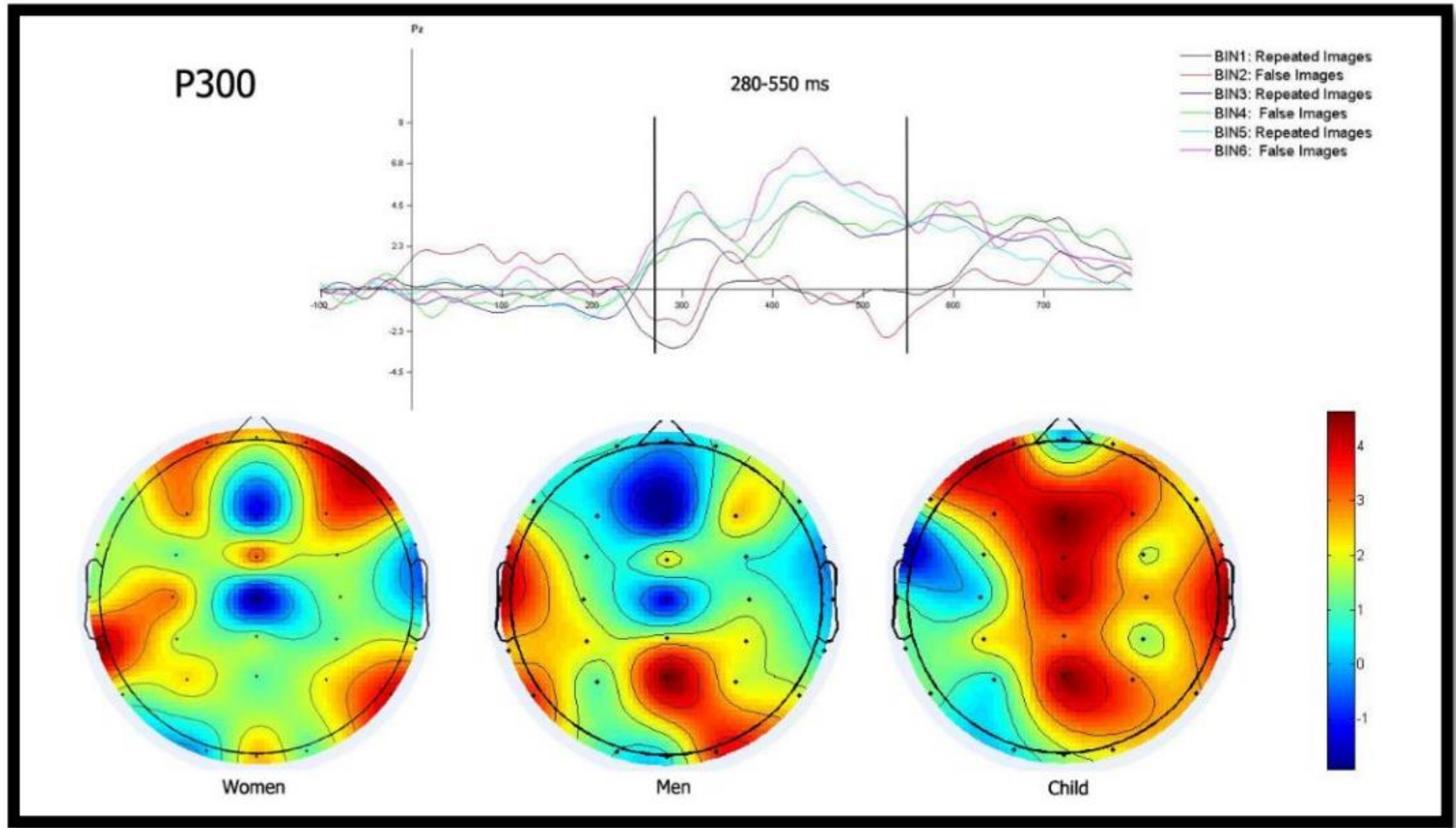


Fig. 4.8 . Shabani, M . Jan 2019 . Create a false memory based on your own life ads A letter with a growth attitude . Thesis



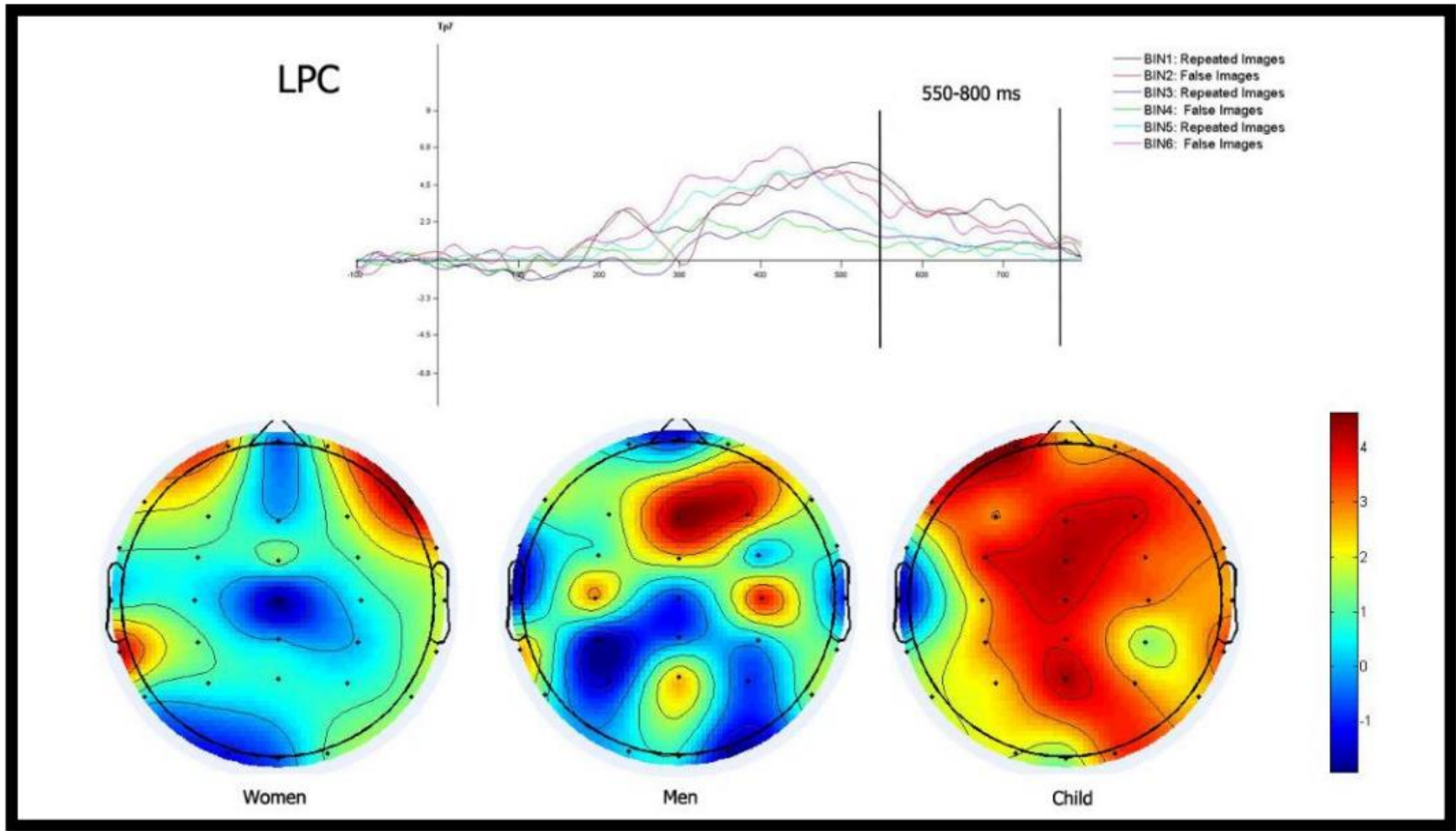


Fig. 4.10 . Shabani, M . Jan 2019 . Create a false memory based on your own life ads A letter with a growth attitude . Thesis



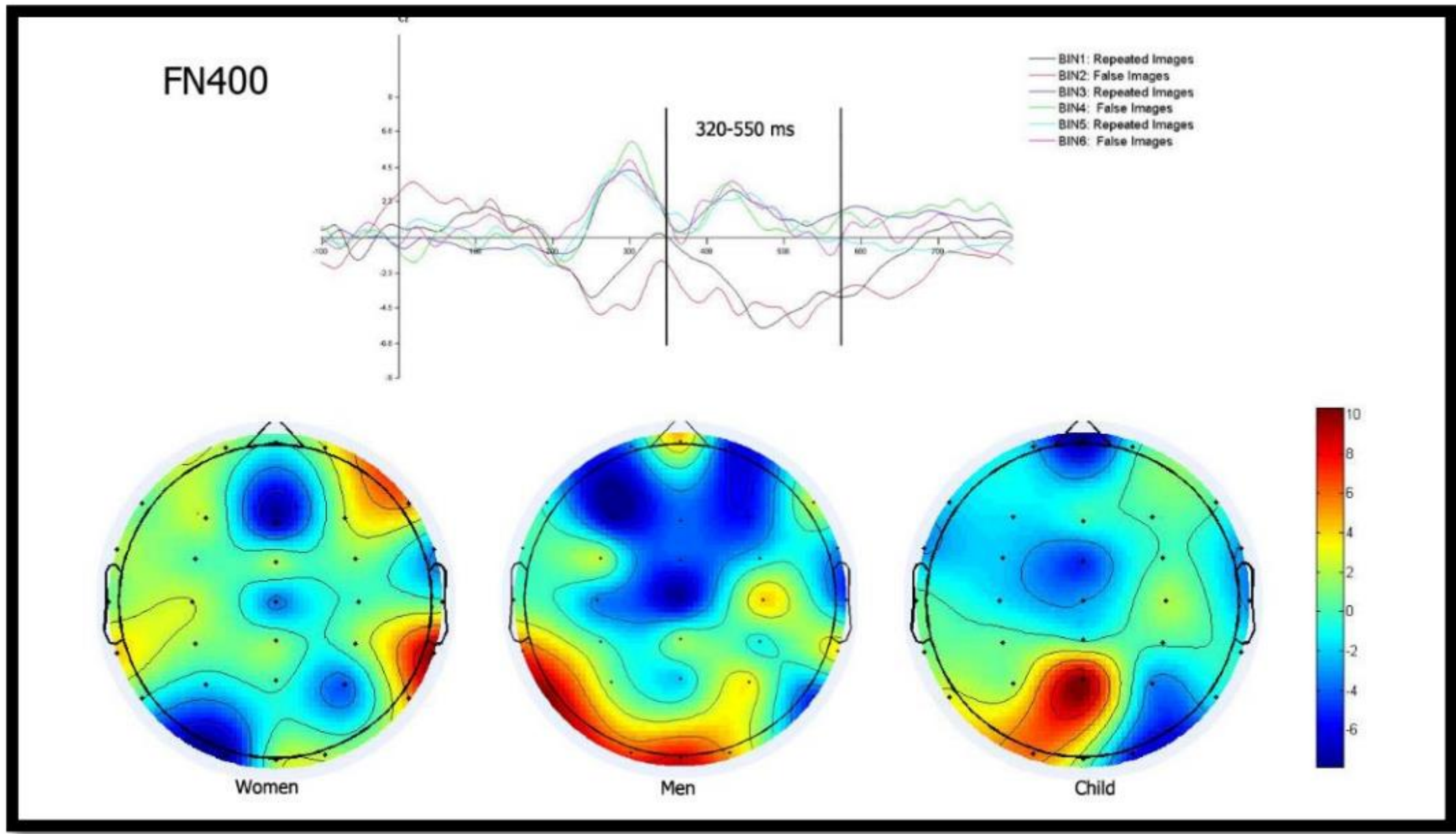


Fig. 4.12 . Shabani, M . Jan 2019 . Create a false memory based on your own life ads A letter with a growth attitude . Thesis



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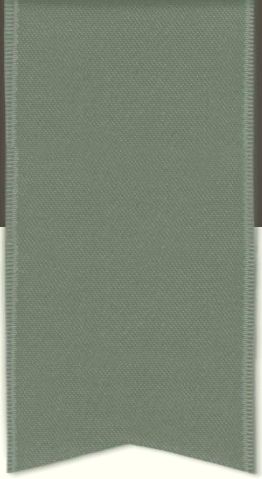
# STUDY & RESULTS

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# Pipeline

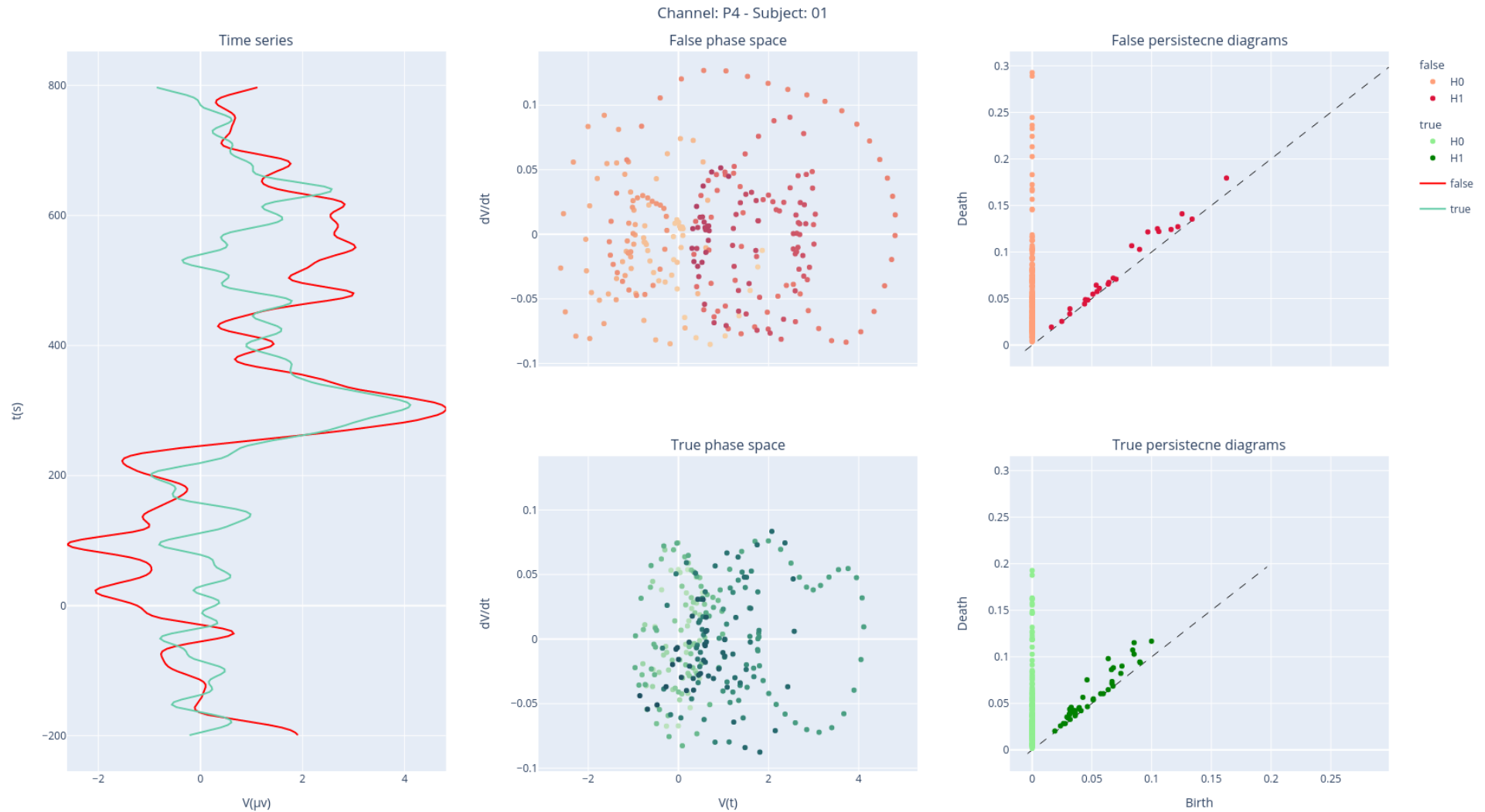
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- Original time series and shuffled ones
- Differential phase space:  $V(t), \frac{\Delta V(t)}{\Delta t}$
- Vietoris Rips, 45 PH features, radius of gyration
- T-statistics, p-values, effect-size, confidence level
- Conditions:
  - Feature A:  $P_{A-\bar{A}} < \alpha, P_{A-A_{sh}} < \alpha, P_{\bar{A}-\bar{A}_{sh}} < \alpha$
- Multiple comparison corrections:
  - FDR
- Violin plots of features, topographs, etc. to find best features

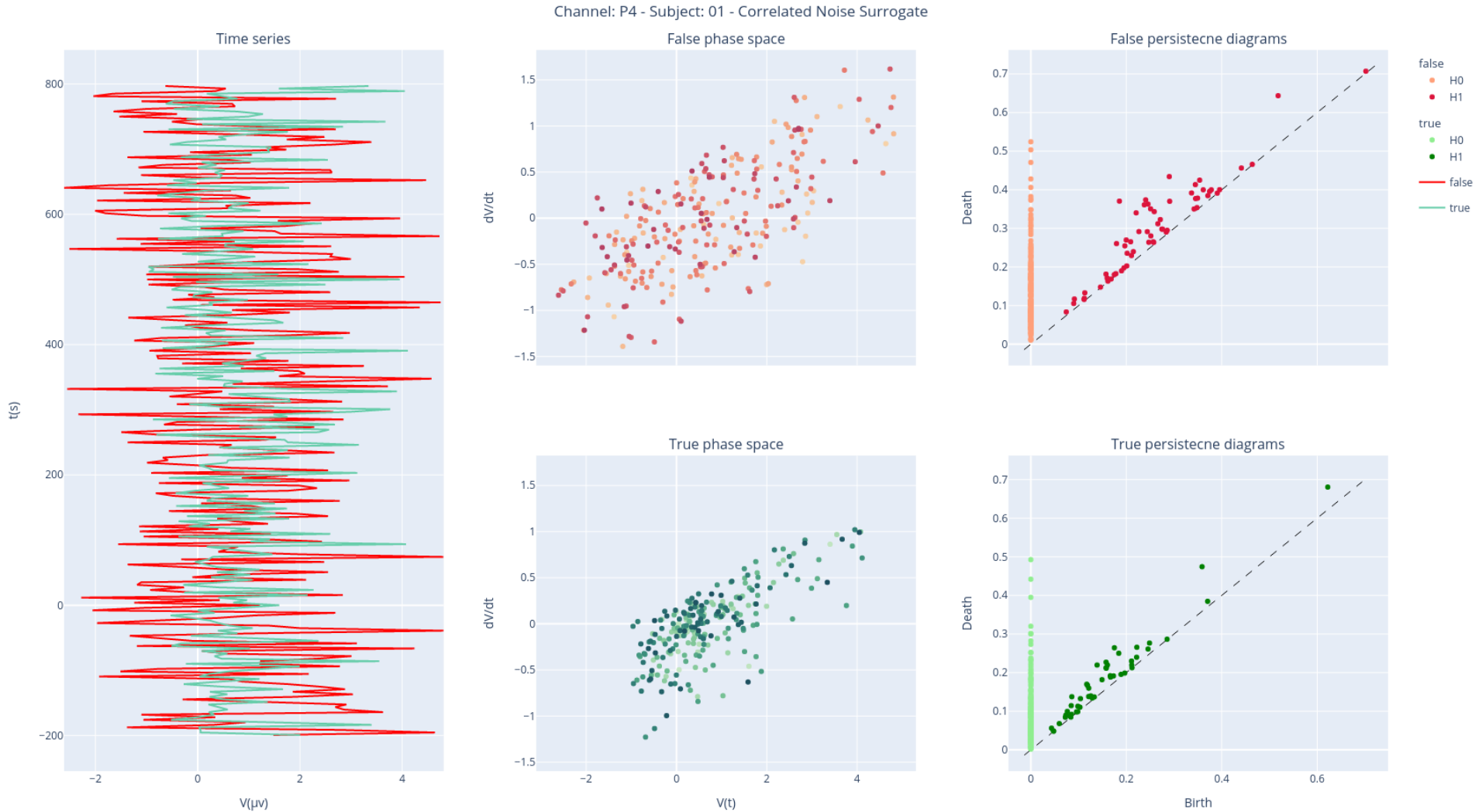


# SAMPLE REPRESENTATIONS

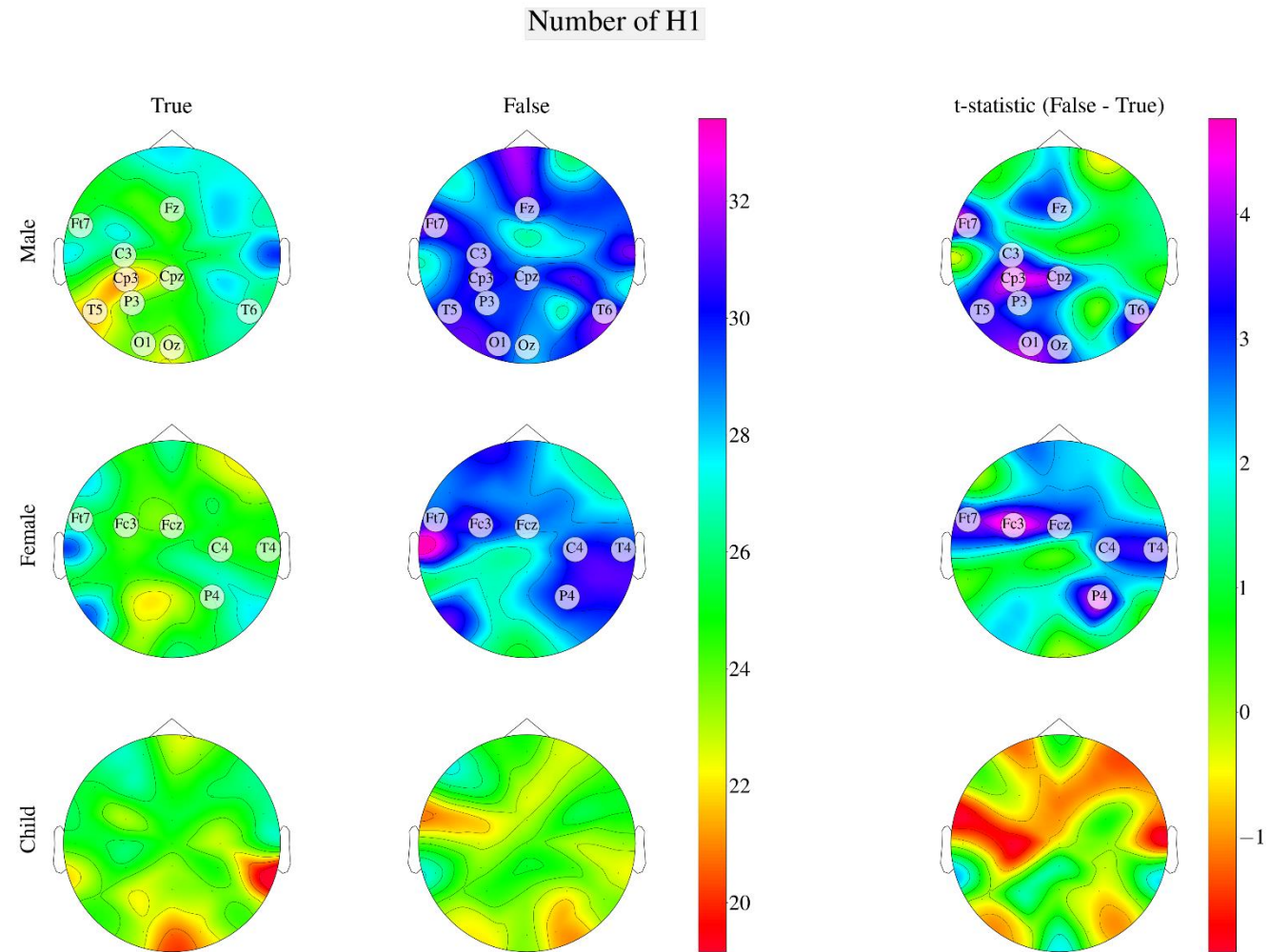
# Time Series, Phase Spaces, and Persistent Diagrams



# Time Series, Phase Spaces, and Persistent Diagrams

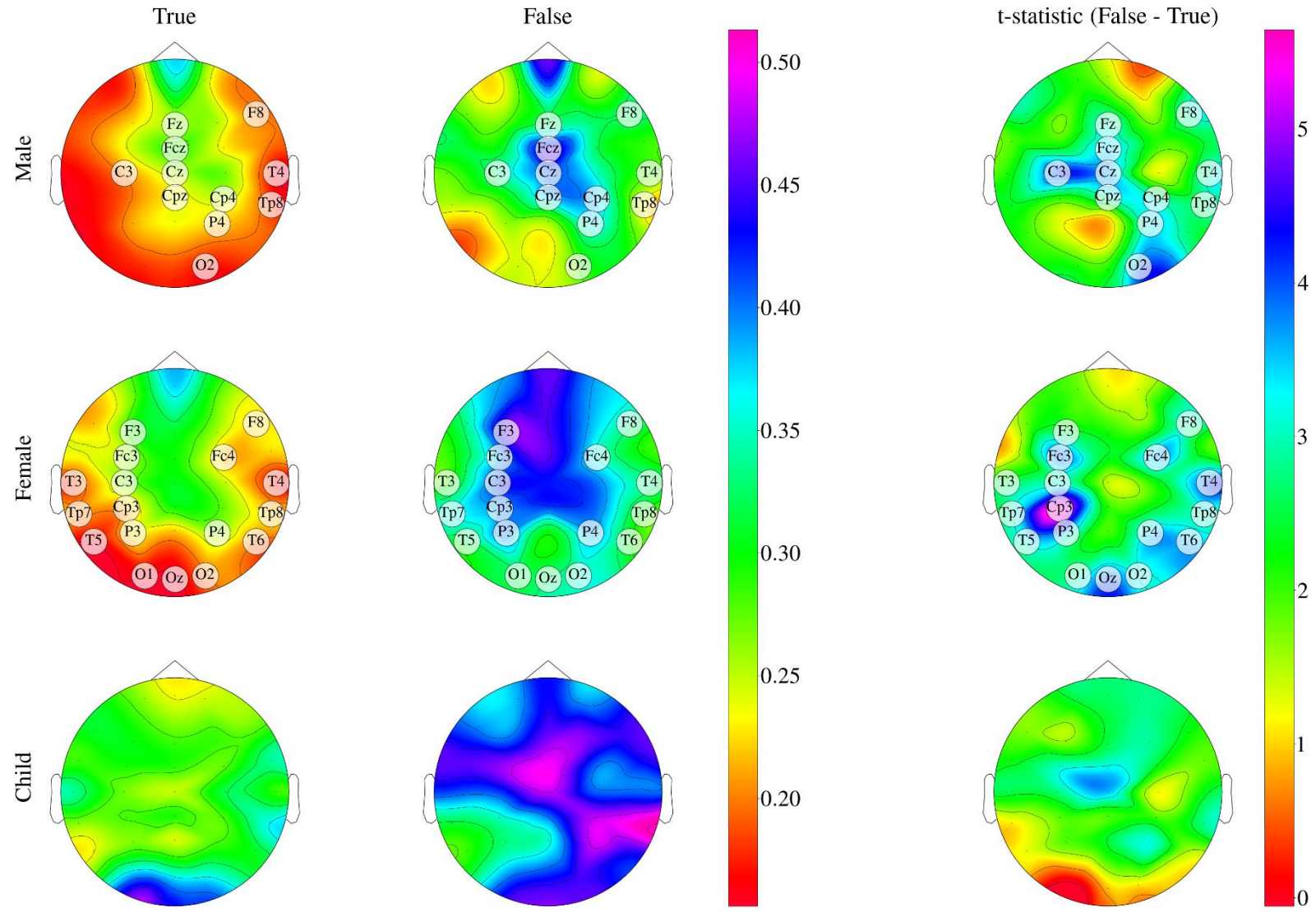


# Topographs



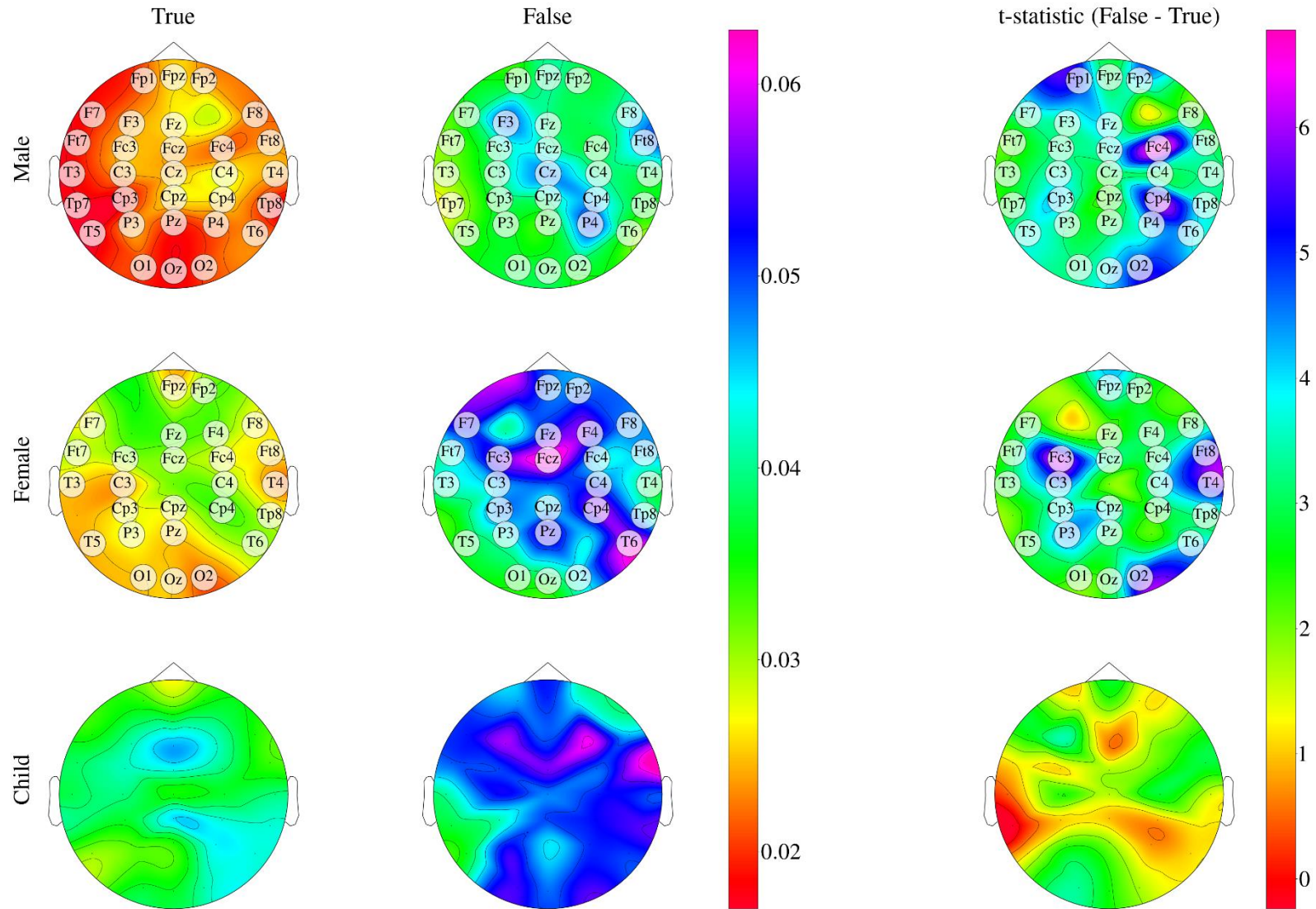


# Bottleneck Amplitude H0

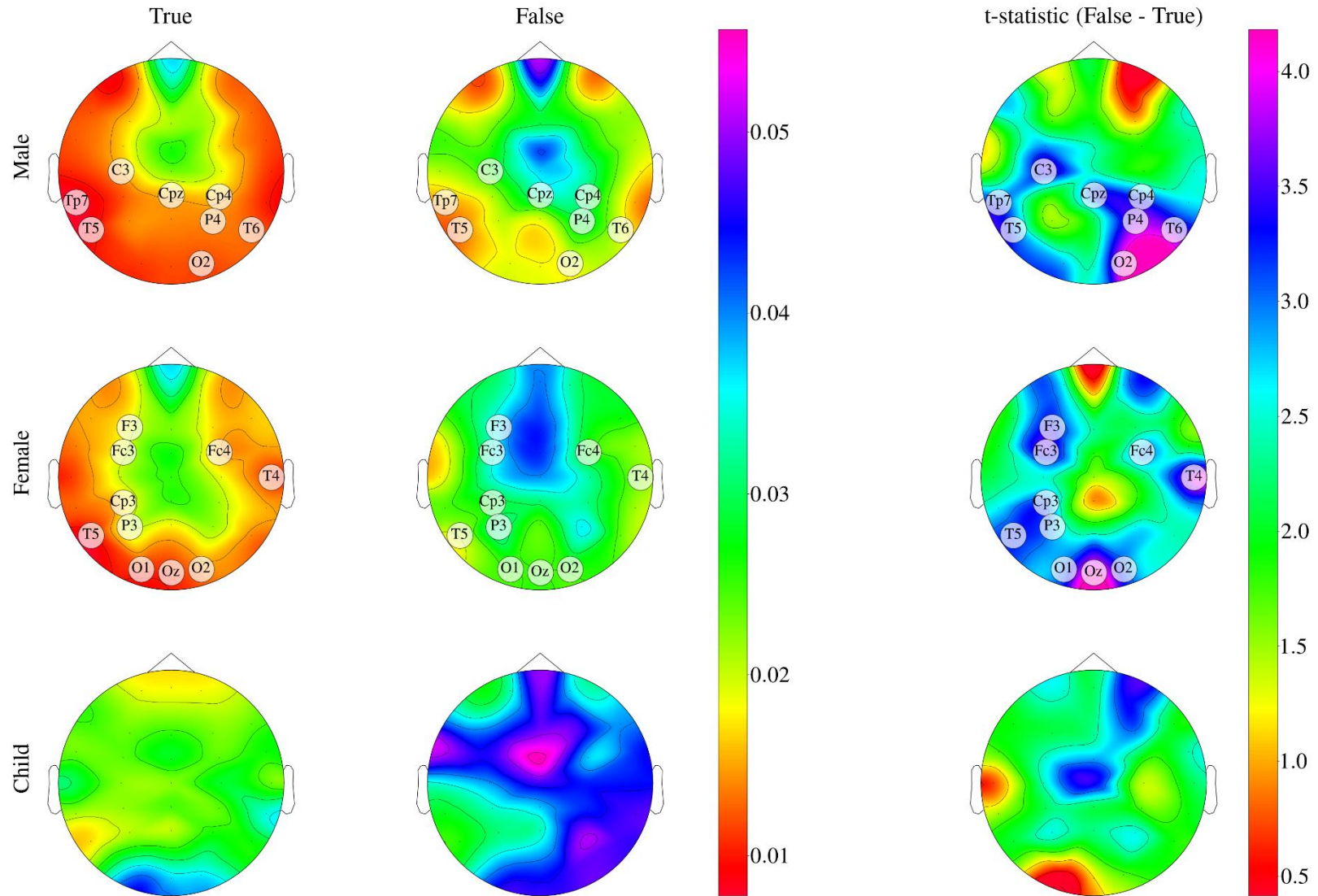




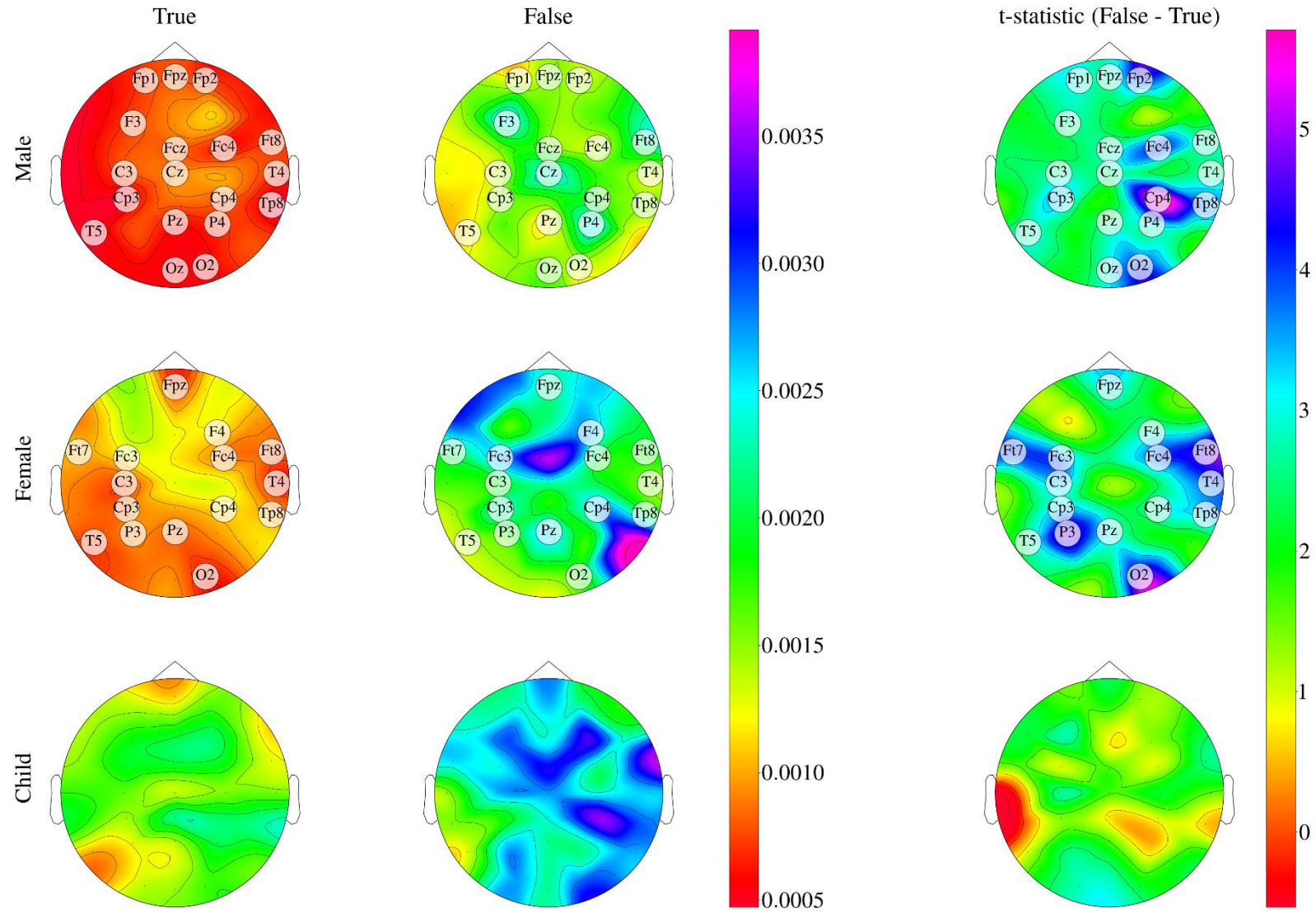
# Bottleneck Amplitude H1



# Silhouette Amplitude H0

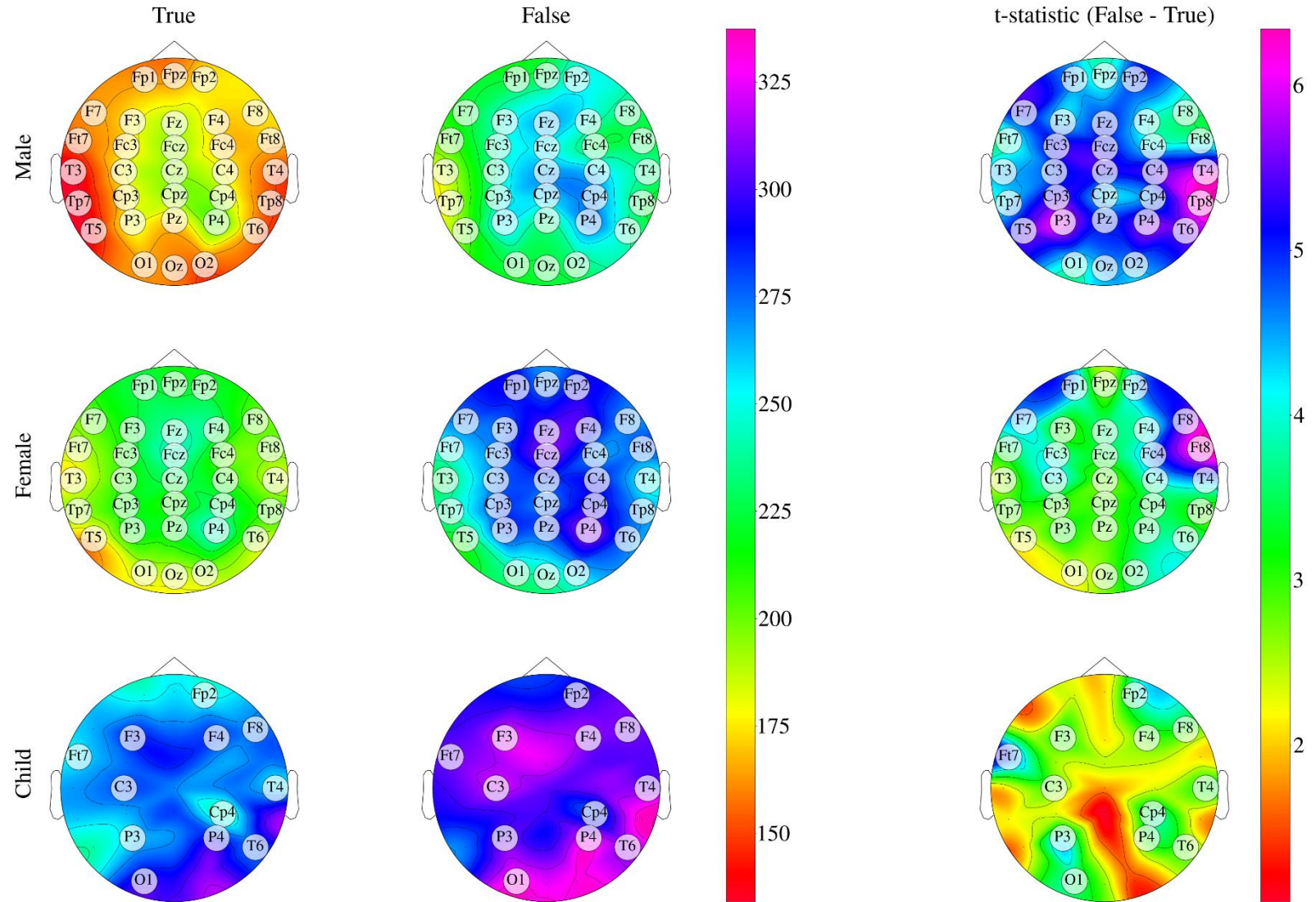


# Silhouette Amplitude H1

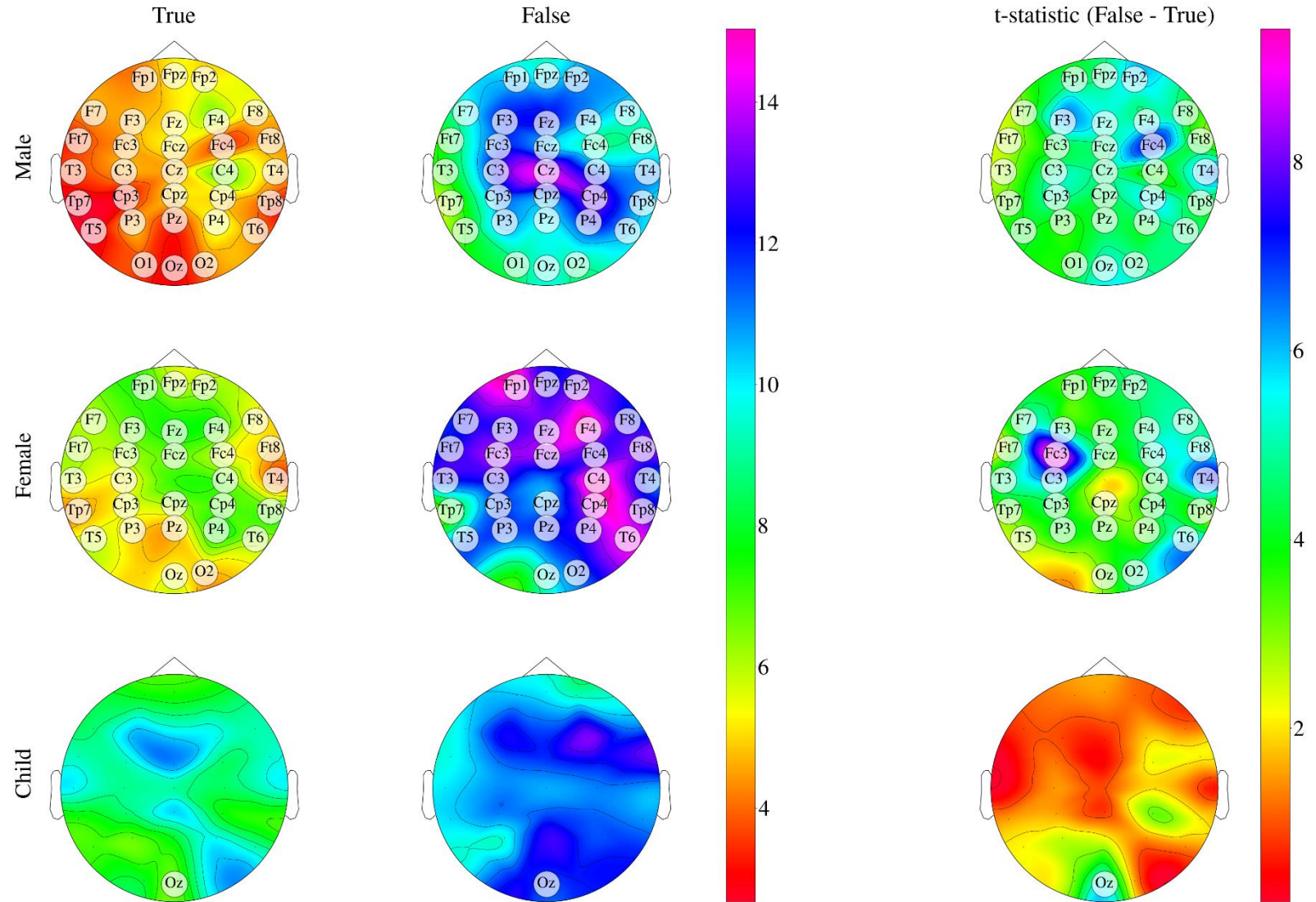




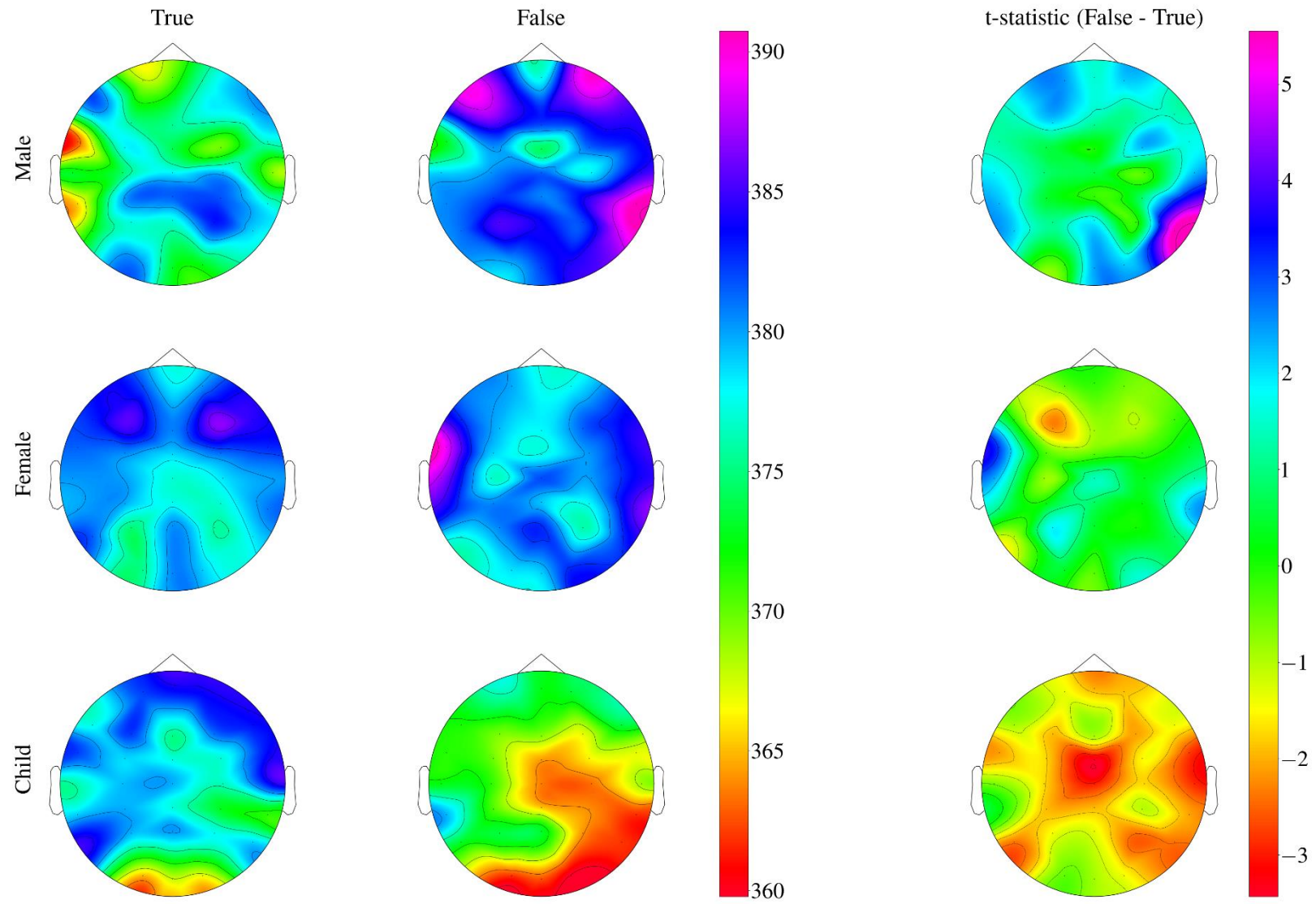
# Heat Amplitude H0



# Heat Amplitude H1

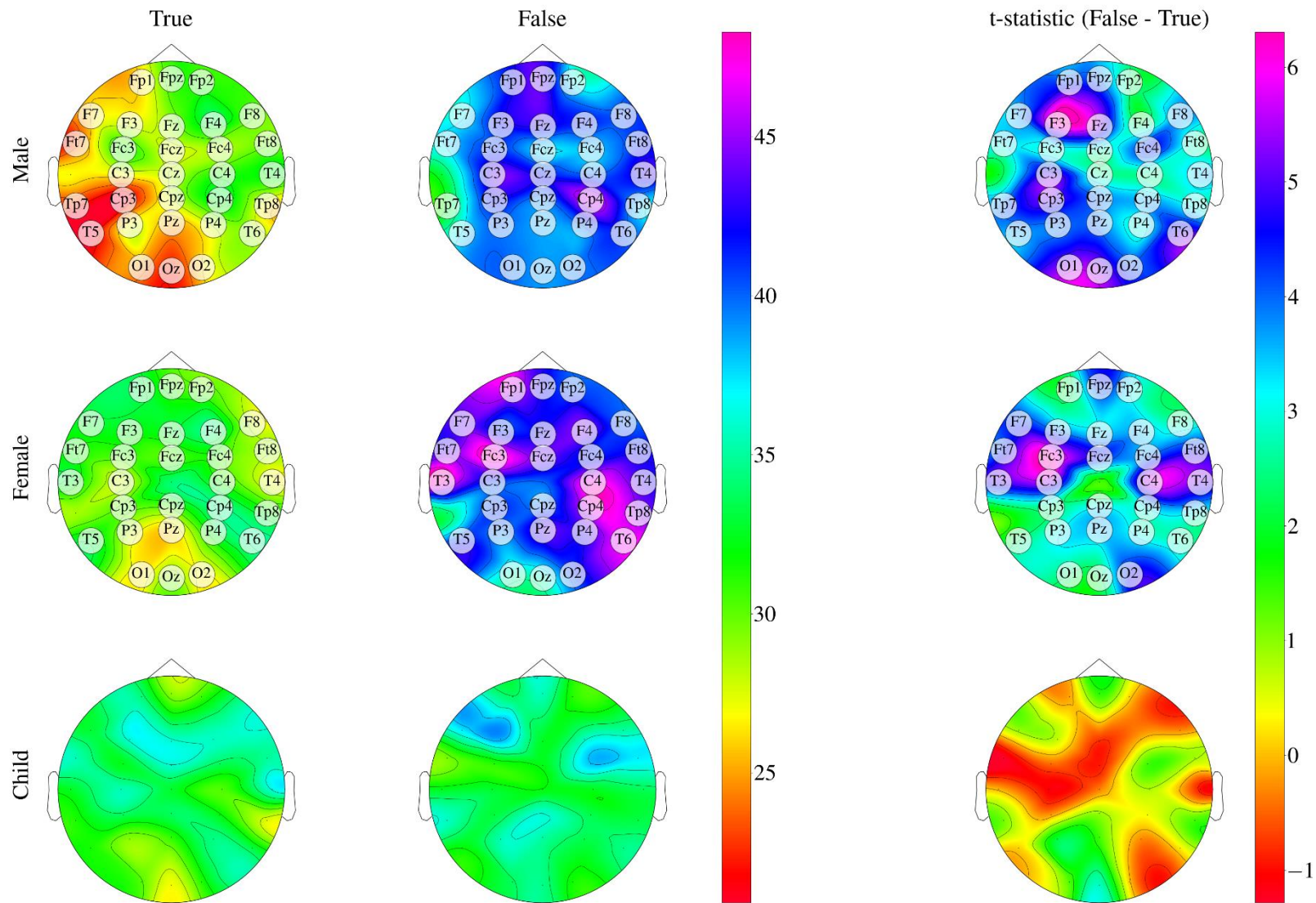


# Persistence Image Amplitude H0

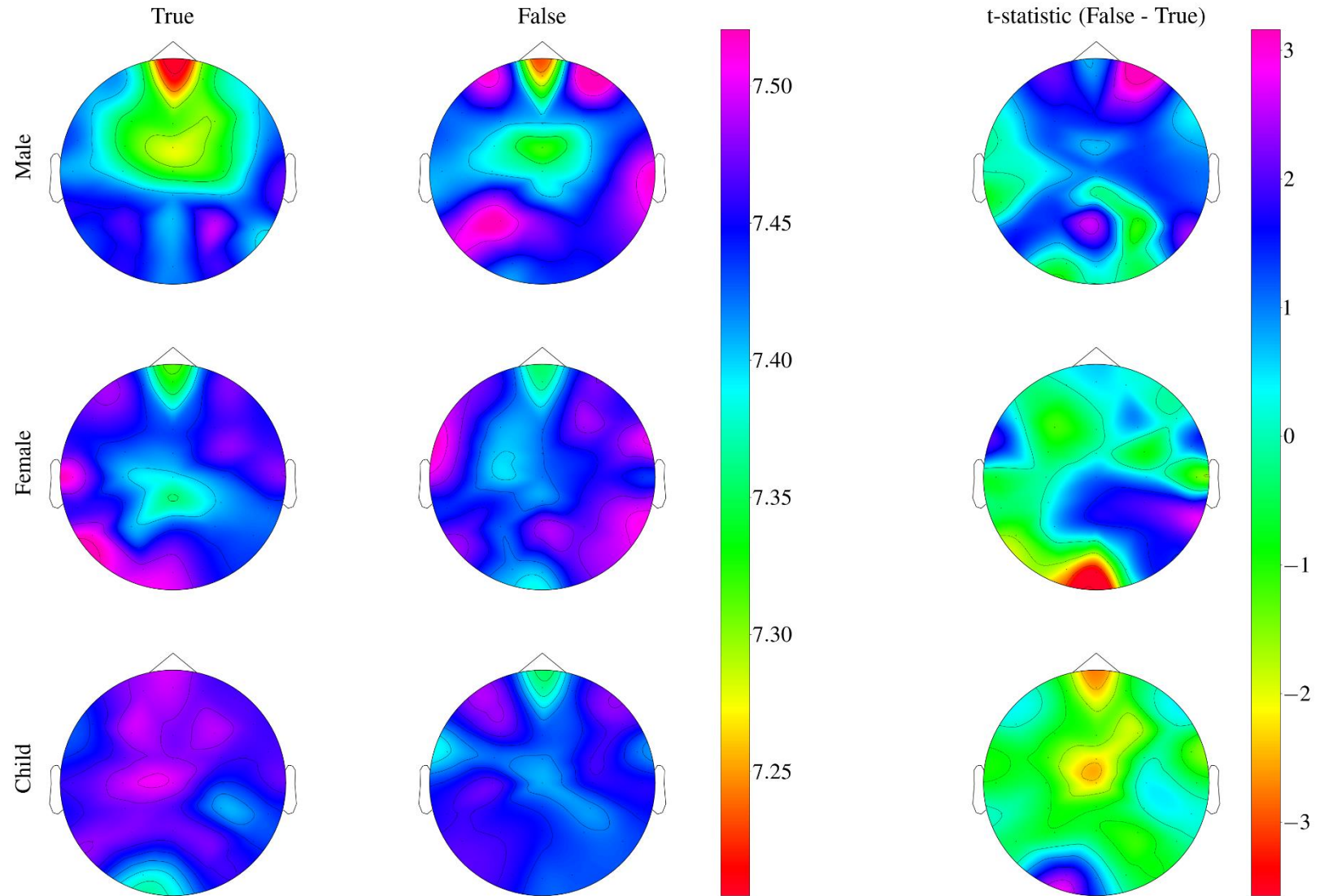




# Persistence Image Amplitude H1

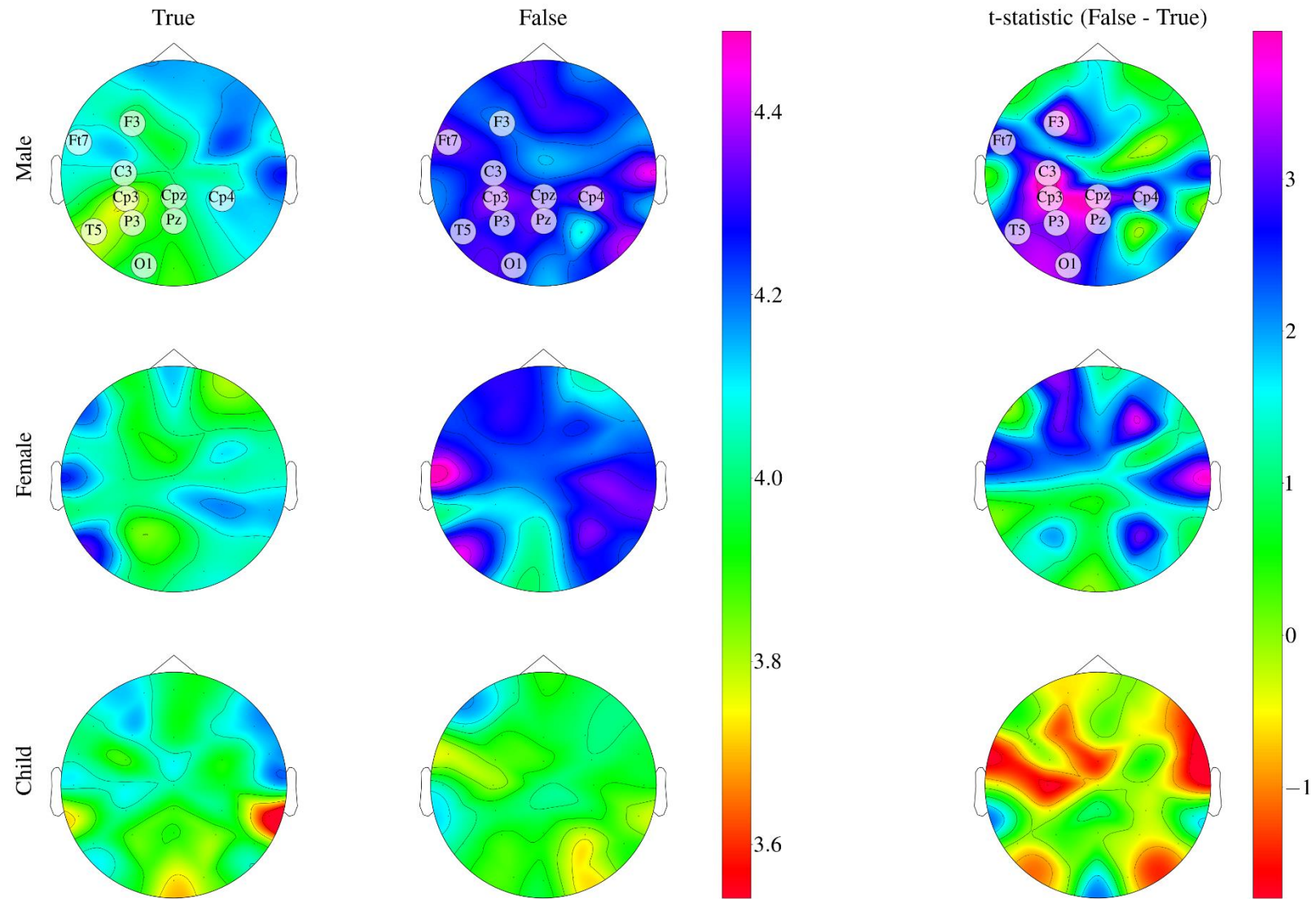


# Persistence Entropy H0

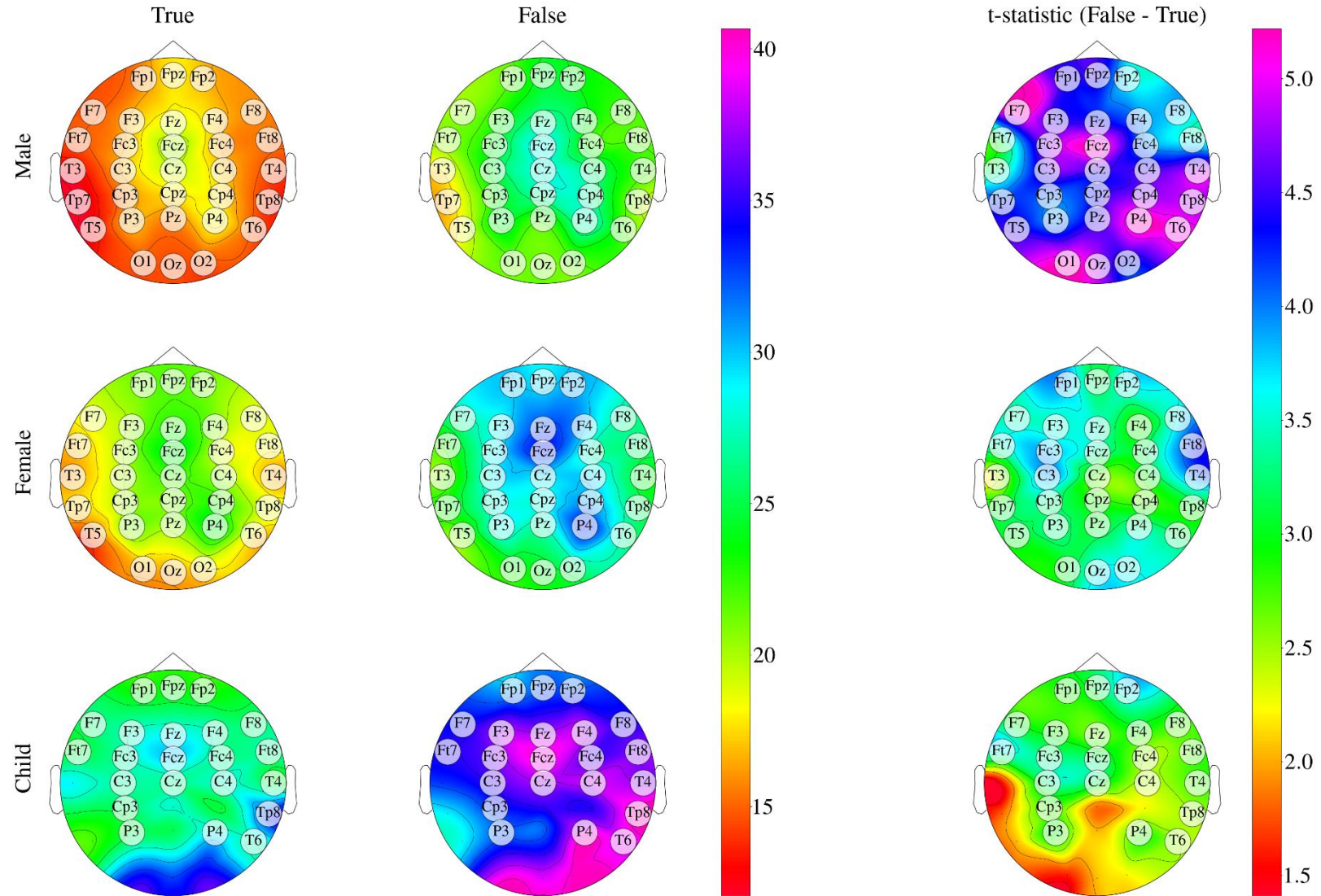




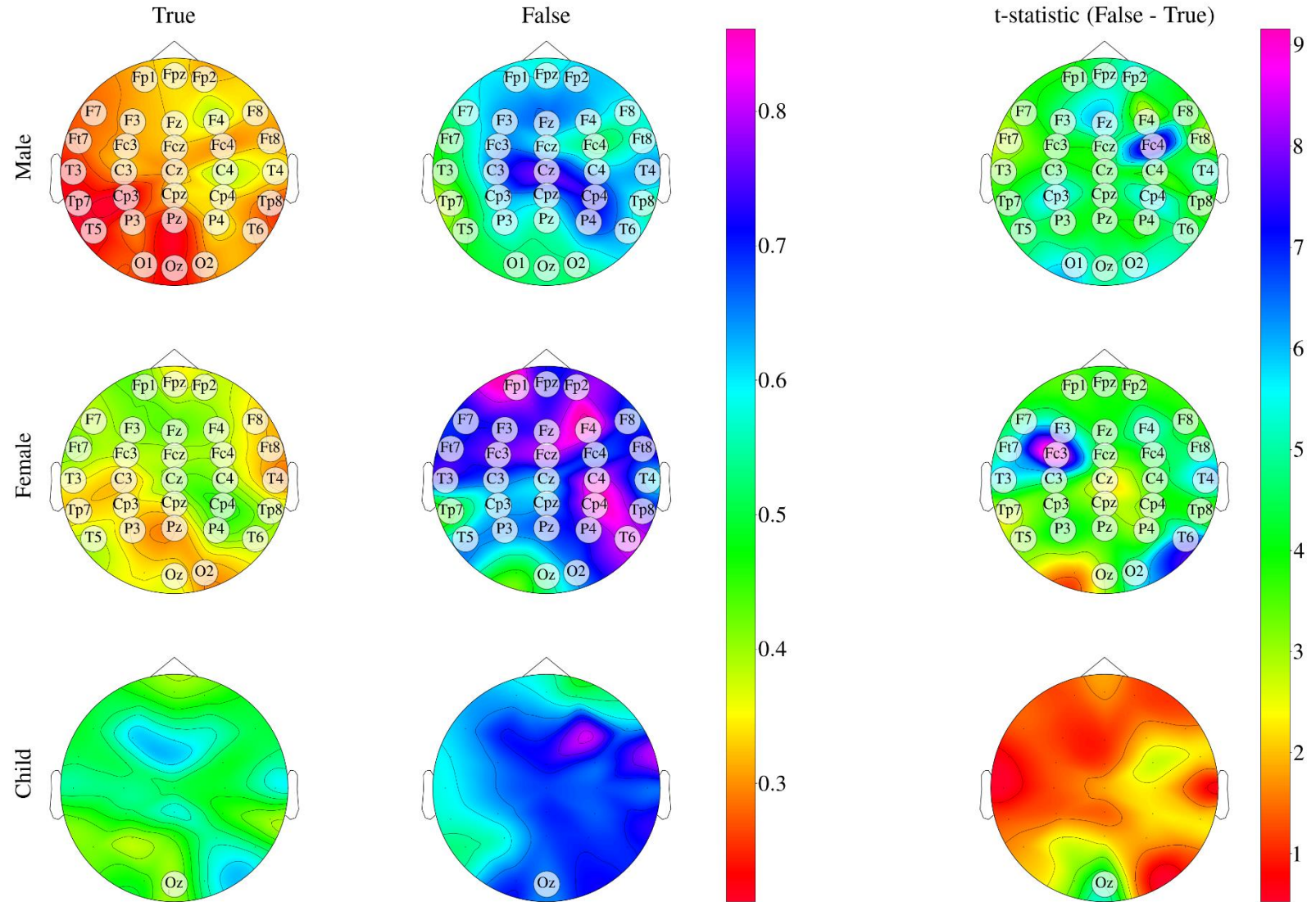
# Persistence Entropy H1



# Area under Betti Curve H0

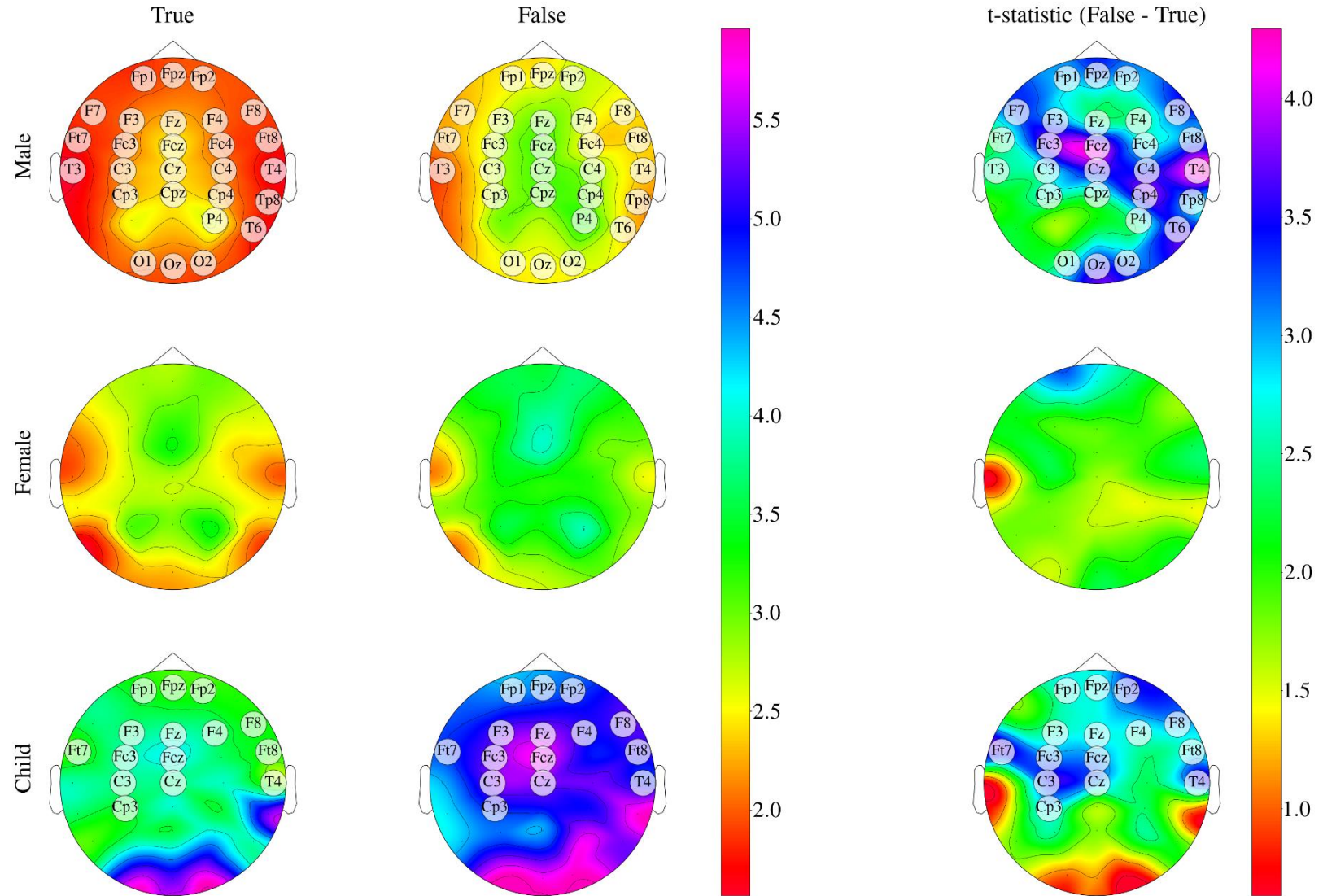


# Area under Betti Curve H1

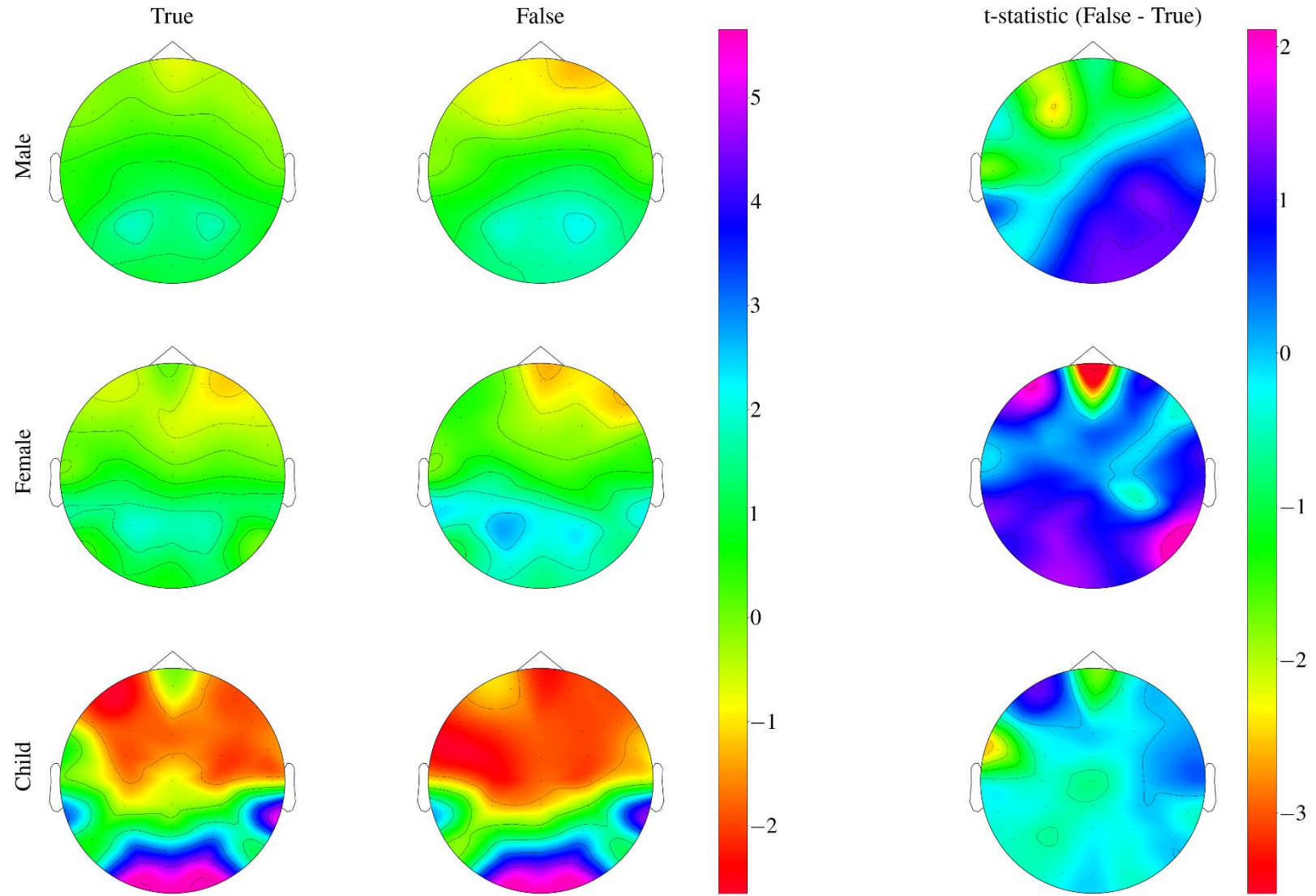




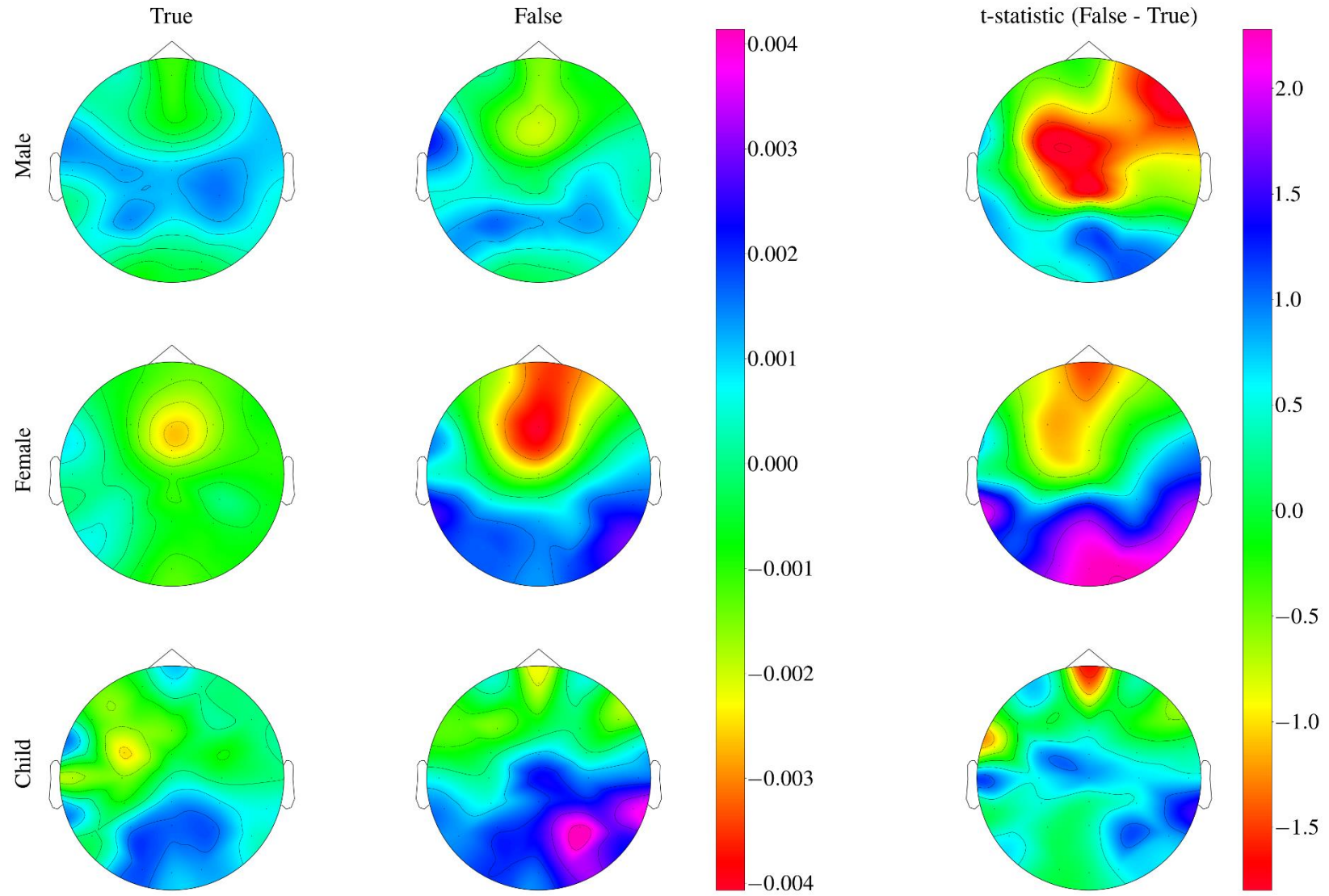
# Radius of Gyration

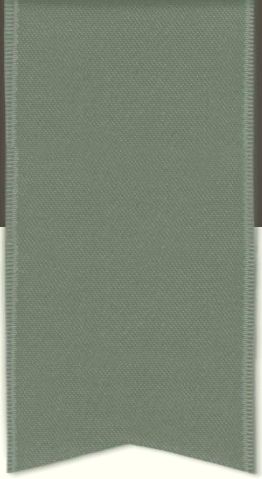


# x Center of Mass



# y Center of Mass



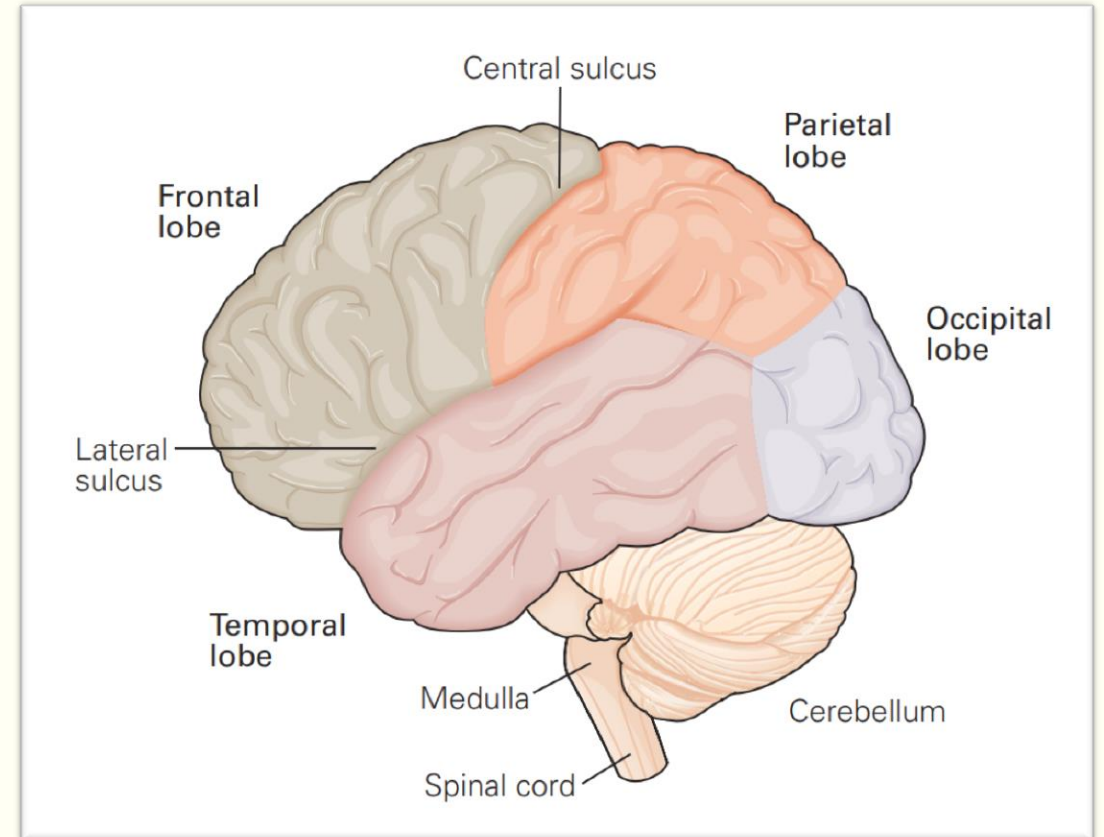


# CONCLUSION

# Cognitive Roles of Different Regions

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- **Frontal regions** → attention and working memory
- **Central regions** → sensory integration
- **Temporal regions** → auditory processing and language comprehension, the formation and retrieval of memories
- **Parietal regions** → spatial and cognitive processing, spatial awareness
- **Occipital regions** → visual processing, distinguishing seen and unseen





# Results

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- The large effect sizes → substantial differences
- **Children** → developmental or methodological factors
- **Females** → more detailed:
  - analytical reasoning
  - sensory evaluation,
  - analysis of verbal and emotional content
  - visual details
  - a balanced approach with a significant focus on spatial processing,
- **Men** → more auditory cues
- Different combinations of cognitive functions in processing memories
- Synchrony
- H1 for children
- Heat amplitude value in children

*The difference between false memories and true ones is the same as for jewels: it is always the false ones that look the most real, the most brilliant.*

*Salvador Dali*

