Frequency Domain Analysis on Infants and Adults EEG

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Abstract

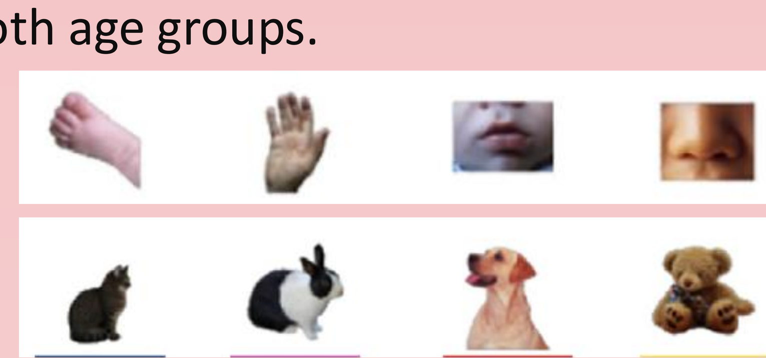
This study investigated developmental differences in EEG patterns between infants and adults during object recognition tasks, focusing on frequency domain analysis. EEG data from both groups were analyzed using Fast Fourier Transform to convert time-domain data into the frequency domain. We examined 18 features, including individual band powers, power ratios, and spectral slopes across 18 nodes in frontal, occipital, posterior, and parietal regions. Support Vector Machines (SVM) were used for classification. Combining all frequency bands yielded the highest accuracy (93.55%) in distinguishing infant and adult EEG patterns, with the theta/(alpha+beta) ratio showing the highest individual accuracy (94.38%). Spatially, posterior regions, particularly the occipital and parietal areas, were most informative. Frequency band permutation analysis revealed optimal ranges for differentiation, with theta [4-9 Hz], alpha [9-12 Hz], and beta [12-30 Hz] achieving 96.60% accuracy, led by the theta/(alpha+beta) ratio feature. Coherence topographical maps showed lower posterior activation in infants compared to adults. These findings provide insights into neural development during visual recognition, suggesting the maturation of visual processing networks from infancy to adulthood. The results have potential applications in developing early intervention strategies for cognitive disorders and inform future research on atypical developmental trajectories.

Introduction

- **Objective**: Investigate EEG frequency differences between infants and adults during object recognition tasks.
- **Significance**: Understanding developmental changes in visual processing can inform cognitive development and early intervention strategies for neurodevelopmental disorders.
- **Methodology**: EEG frequency domain analysis applied to data from infants and adults using Fast Fourier Transform (FFT).

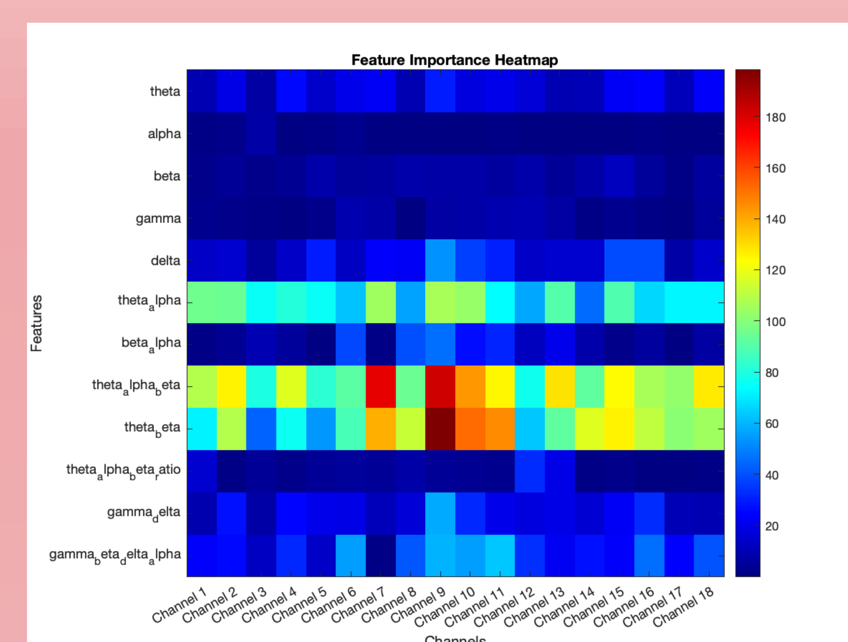
Methodology

- **Data Collection**: EEG during object-viewing tasks from both age groups.



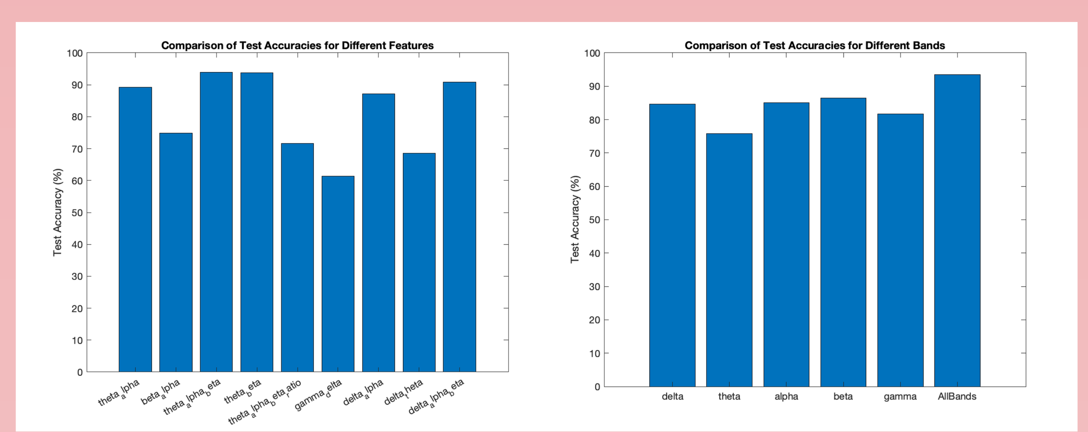
- **Processing**: Frequency analysis using periodogram, feature selection via ANOVA, and classification with Support Vector Machines (SVM).
- **Feature Extraction**: 18 features analyzed across key brain regions.

Results

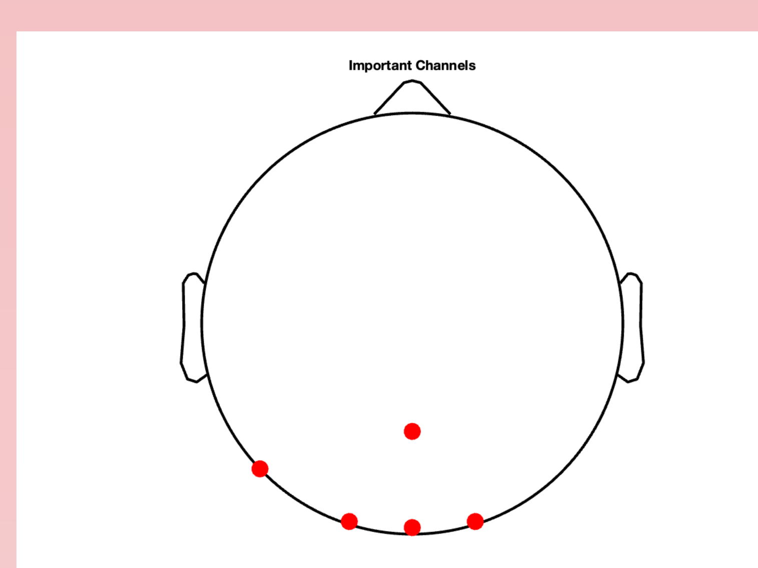


1. Single Band Power Analysis
- Highest individual accuracy: Beta band (87.01%)
- All bands combined: 93.55% accuracy
- Indicates importance of integrating information across frequency ranges

2. Band Power Ratio Analysis
- Theta/(alpha+beta) ratio: Highest accuracy (94.38%)
- Theta/beta ratio: Close second (94.26%)
- Highlights importance of theta activity relative to higher frequency bands

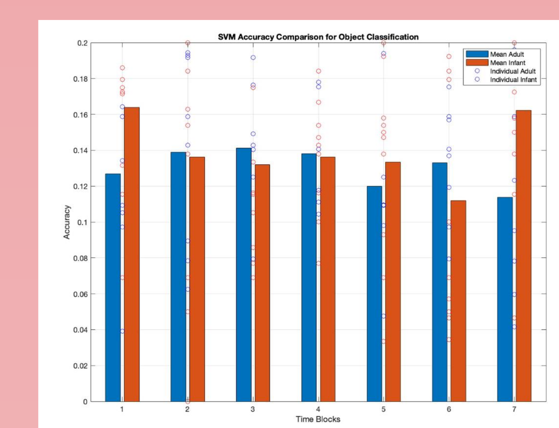


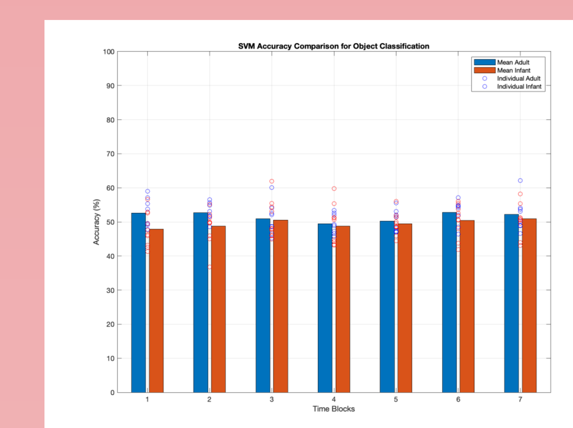
3. Channel Importance
- Most informative channels: Posterior region (occipital and parietal areas)
- Aligns with known involvement of these regions in visual processing



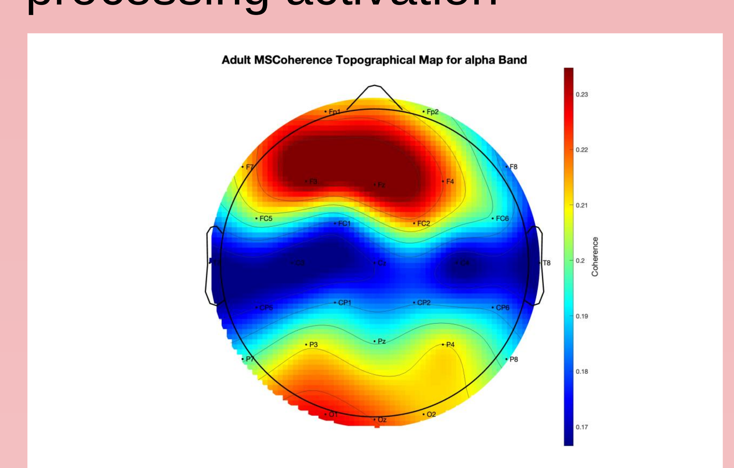
4. Frequency Band Permutation
- Optimal ranges: theta [4-9], alpha [8-12], beta [12-30] Hz
- Highest accuracy achieved: 96.60%

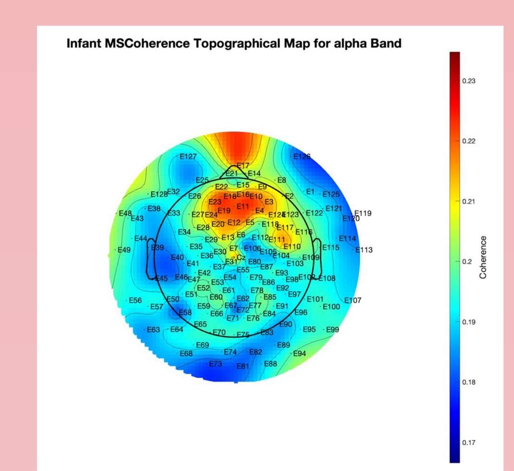
5. Object Classification Comparison
- There are no significant accuracy differences between adult and infant groups
- Mean accuracies around the chance level (12.5%) with 8 ways classification and chance level (50%) for pairwise comparison
- Suggests similar performance in object distinction tasks





6. Coherence Topographical Maps (Alpha waves)
- Frontal regions: Low coherence values in both adults and infants
- Posterior regions: Adults showed higher activation compared to infants
- Indicates developmental differences in visual processing activation





Discussion

1. **Frequency Band Distinctions**:
- Beta band dominance in adults (87.01% accuracy) suggests more developed attention and cognitive control.
- Strong delta activity in infants reflects ongoing brain maturation, while the theta/(alpha+beta) ratio (94.38%) is crucial in distinguishing age groups, highlighting the importance of theta oscillations in early development.

2. **Spatial Patterns**:
- Occipital and parietal regions were the most informative, showing greater activation in adults. Lower activation in infants suggests ongoing development of visual networks.

3. **Frequency Range Optimization**:
- Theta, alpha, and beta frequency bands achieved the highest classification accuracy (96.60%), indicating developmental shifts in brain wave activity related to cognitive processing.

4. **Object Recognition**:
- Neural representations of objects were similar within each age group, indicating that object recognition involves more complex dynamics than captured by current frequency analysis methods.

Conclusion

Our study demonstrates significant EEG differences between infants and adults during object recognition tasks, particularly with the theta/(alpha+beta) ratio, highlighting key developmental changes in visual processing. The prominence of posterior channels, especially in occipital and parietal regions, underscores the maturation of visual networks.

These findings offer valuable insights into brain development, suggesting ongoing maturation of visual systems in infants. This detailed characterization of electrophysiological differences enhances our understanding of developmental neural trajectories in visual processing.

The results have practical implications for creating age-specific cognitive assessment tools and guiding early interventions for developmental disorders related to visual processing. Additionally, these insights pave the way for future research on brain plasticity and the neural mechanisms of object recognition during development.

Implications and Future Directions

Our findings offer key insights into the maturation of brain functions related to visual cognition:

- High accuracy in distinguishing infant and adult EEG patterns, particularly using the theta/(alpha+beta) ratio, indicates significant developmental changes in neural processing and supports increasing neural specialization with age.
- The prominence of posterior channels, especially in occipital and parietal regions, highlights their role in visual processing. Reduced activation in infant posterior regions suggests ongoing maturation.
- These results provide a quantitative basis for studying the plasticity of visual processing networks from infancy to adulthood.
- EEG frequency band analysis demonstrates its potential as a non-invasive tool for tracking neurodevelopmental changes, aiding in early cognitive assessments, and detecting atypical developmental trajectories.

Acknowledgements

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