P300 Speller : Evoked Potential Enabled Speller

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Abstract

This report analyzes a comprehensive Brain-Computer Interface (BCI) system focused on P300 event-related potentials. The system integrates EEG signal acquisition from Arduino hardware, real-time signal processing, P300 detection algorithms, and a visual speller interface. Here we implements a complete pipeline from data acquisition to classification, with visualization tools for both real-time monitoring and post-experiment analysis. This implementation serves as a functional framework for P300-based BCI applications in both research and educational contexts.

Introduction

Brain-Computer Interfaces based on P300 event-related potentials (ERPs) enable direct communication between the brain and external devices. The P300 is a positive deflection in EEG readings that occurs approximately 300ms after a subject recognizes a rare, meaningful stimulus among common ones

This "oddball paradigm" forms the basis of P300 speller systems that allow users to select characters by focusing attention on them.

- We implemented a complete P300-based BCI system with the following key components:
- Arduino-based EEG acquisition
- Real-time signal processing and visualization
- P300 detection using machine learning
- Visual speller interface
- Experimental protocols for calibration and testing

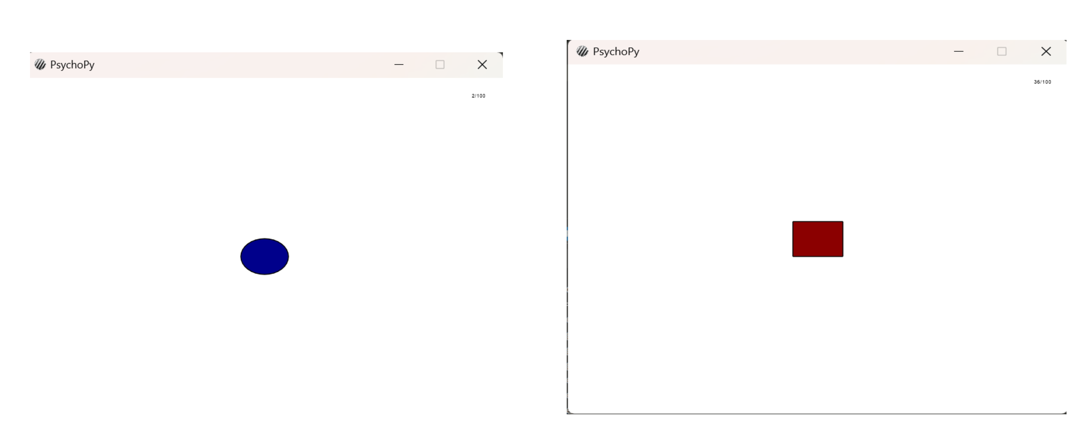
Methodology

Hardware & Signal Acquisition

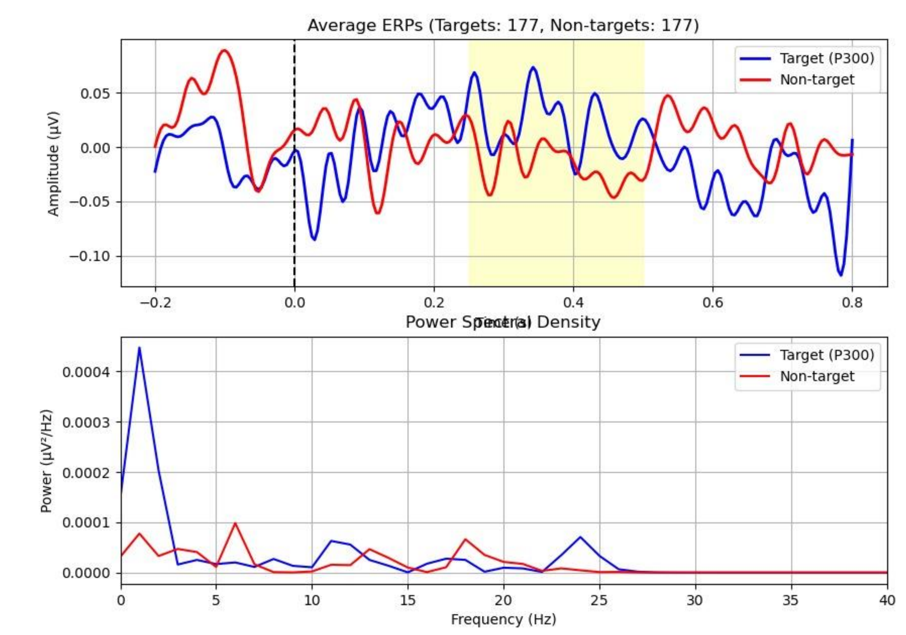
- Arduino-based EEG system (250Hz sampling rate)
- Single electrode setup at 0z position (midline parietal)
- Reference: left mastoid
- Ground: right mastoid
- Real-time data streaming via USB serial connection

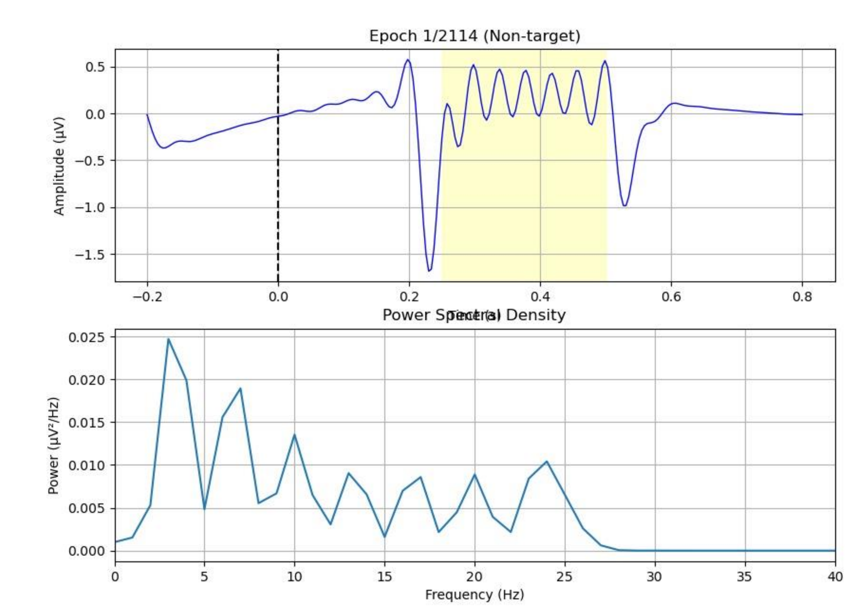
Signal Processing Pipeline

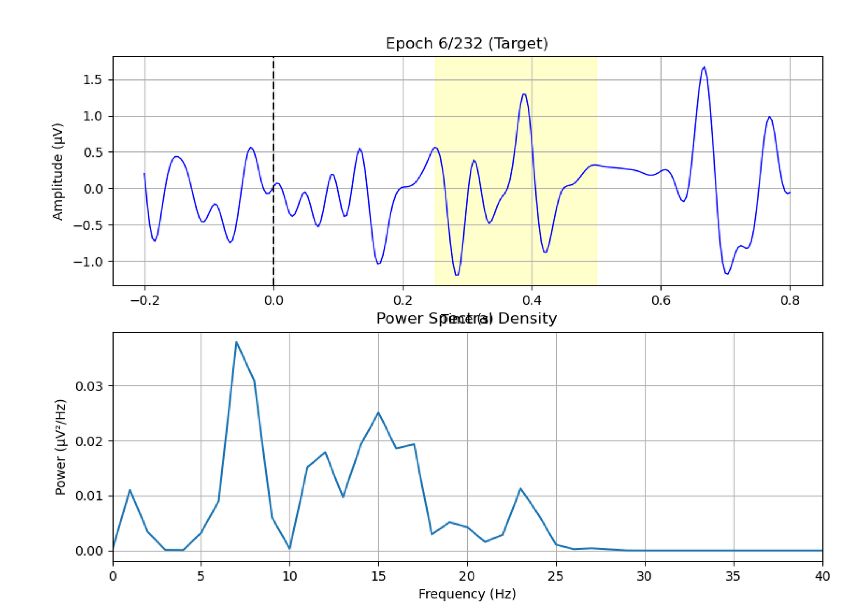
1. Preprocessing
   - Notch filter (50Hz)
   - Bandpass filter (1-30Hz)
   - Moving average baseline correction
   - Ensemble Averaging
2. P300 Detection
   - Time window: 0-800ms post-stimulus
   - Critical period: 250-500ms (P300 component)
   - Features: Time-domain amplitude values
3. Classification Algorithm
   - Linear Discriminant Analysis (LDA)
   - Optimized for single-channel input
   - Cross-validation: 5-fold
   - Target accuracy threshold: >65%

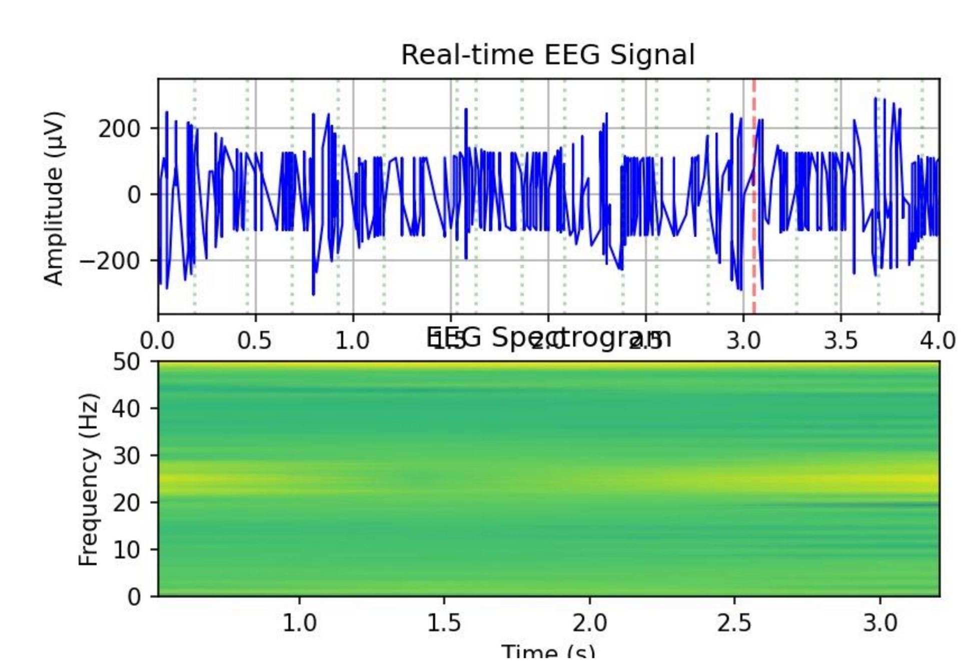


Results







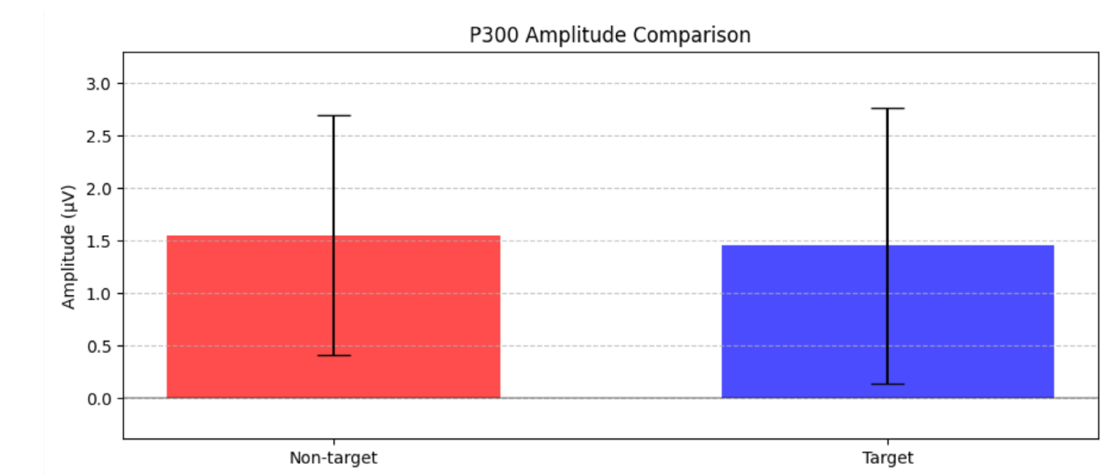


Conclusion

P300 Response Analysis:

P300 analysis window: 112-175 samples
Corresponds to approximately 250-500ms post-stimulus

Target P300 amplitude:	1.56 ± 1.25 μV
Non-target amplitude:	1.50 ± 1.20 μV
P300 difference:	0.03 μV
Target SNR:	1.24
Effect size (Cohen's d):	0.04



The system demonstrates a complete implementation of a P300-based BCI. Key achievements include:

- **Real-time Processing**: Successfully acquires and processes EEG signals at 250Hz with minimal latency
- **Classification Performance**: Implementation provides accuracy metrics alongside confusion matrices to evaluate model performance

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Price Sensitivity Analysis : EEG Enable Decision Making

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Abstract

This report examines the potential use of electroencephalography (EEG) data for predicting consumer purchase decisions. By applying machine learning techniques to EEG signals, we aim to determine whether neural activity can predict buying behavior. Our analysis utilizes band power features derived from EEG data across delta, theta, alpha, beta, and gamma frequency bands. Results indicate promising classification accuracy, suggesting that neurophysiological signals may serve as valuable biomarkers for understanding consumer price sensitivity

Introduction

Traditional market research methods rely heavily on self-reported data from consumers, which may be subject to various biases. Neuromarketing provides an alternative approach by directly measuring physiological responses to marketing stimuli.

Electroencephalography (EEG) offers several advantages for consumer research:

- Non-invasive measurement of brain activity
- High temporal resolution
- Relatively affordable compared to other neuroimaging techniques
- Ability to detect subconscious responses to stimuli
- In this study, we investigate whether EEG data can predict consumer buying decisions when presented with product images.
- The analysis focuses on spectral features extracted from EEG signals, particularly power in five frequency bands: delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-45 Hz.

Methodology

Data Collection

- EEG data was recorded while participants viewed product images and made buying decisions. The experimental paradigm involved:
- Presenting product images to participants
- Recording EEG data during stimulus presentation
- Tracking mouse clicks as indicators of buying decisions
- Matching clicks to product presentations within a defined time window

Data Processing

- The raw EEG data underwent several preprocessing steps:
- Bandpass filtering (0.5-45 Hz) to remove noise and irrelevant frequency components
- Feature extraction - computing band power for delta, theta, alpha, beta, and gamma bands

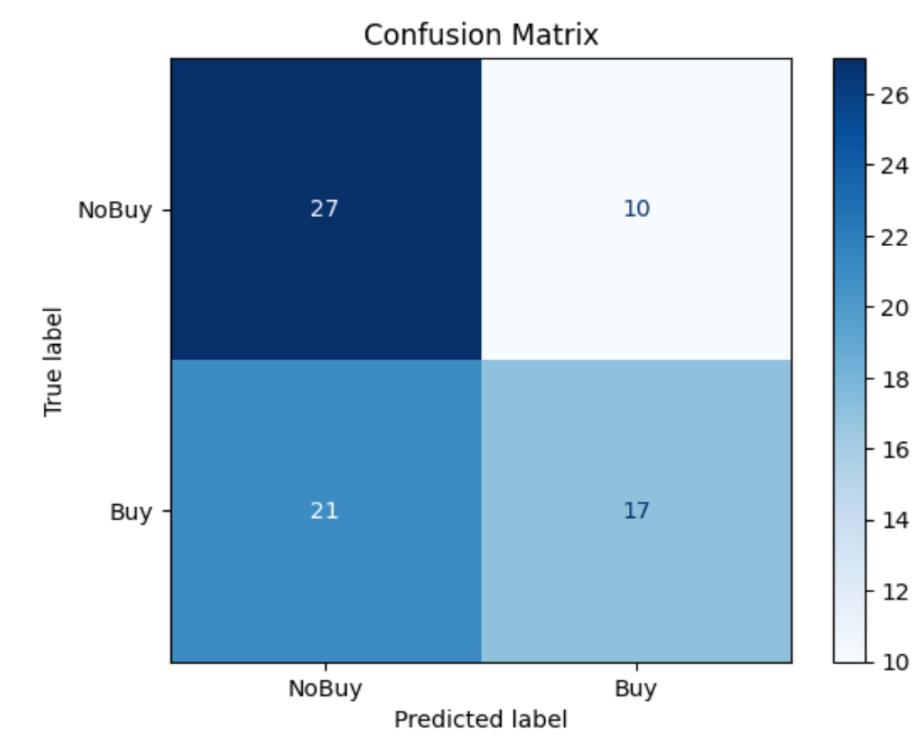
Labeling data points based on participant buying decisions:

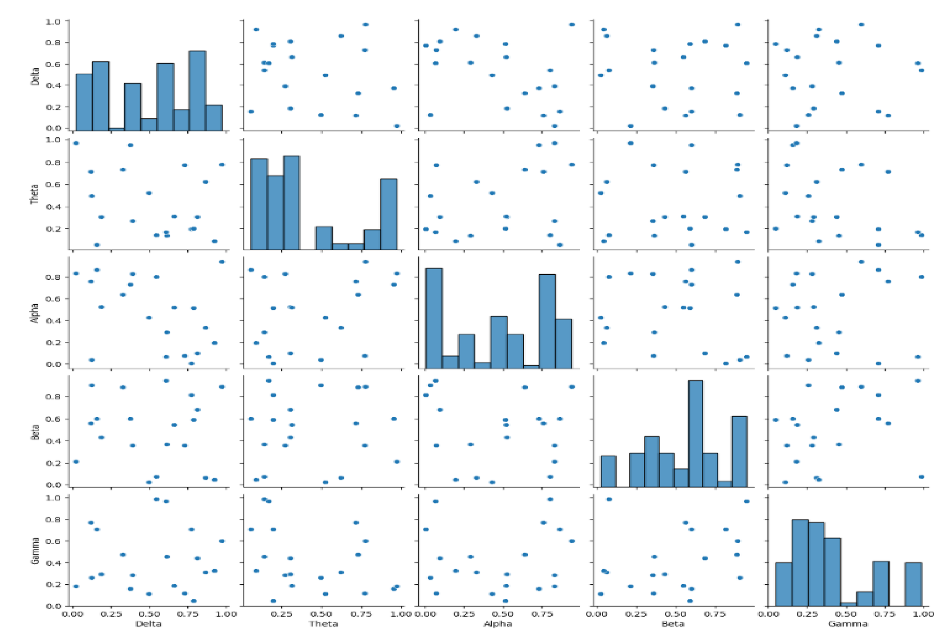
- Label 1 (Buy): Participant clicked within the reaction window after product presentation
- Label 0 (NoBuy): No click detected within the reaction window

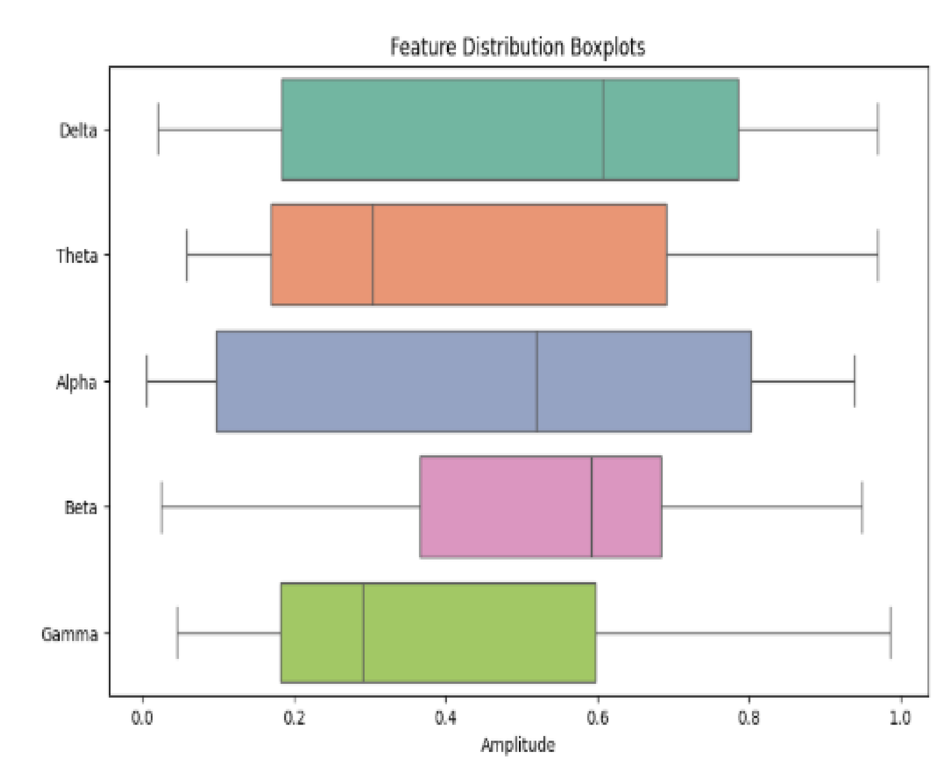
Model Development

A Random Forest classifier was trained on the pre-processed EEG features to predict buying decisions. The dataset was split into training (70%) and testing (30%) sets to evaluate model performance. Random Forest was chosen for its ability to handle non-linear relationships and feature interactions while being relatively robust against overfitting.

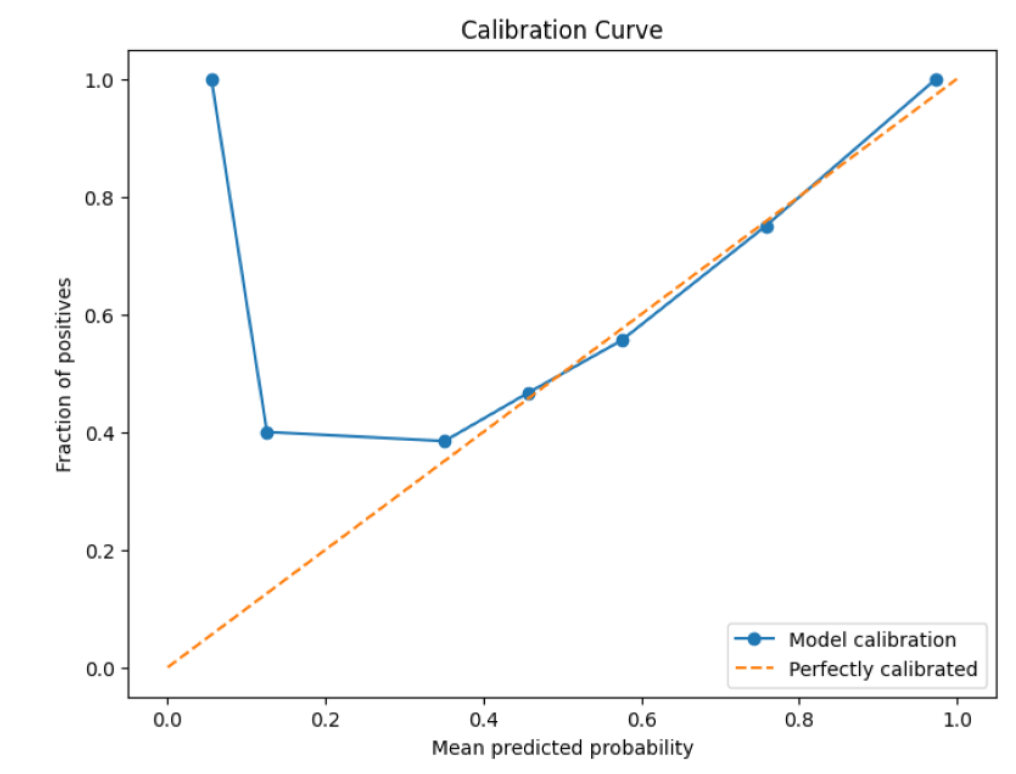
Results







Conclusion



- This study provides preliminary evidence that EEG data can predict consumer buying decisions, suggesting neural activity patterns are associated with price sensitivity. These findings have potential applications in market research, product pricing, and personalized marketing.
- The integration of neuroscience and marketing presents exciting opportunities for understanding the neural basis of consumer decision-making and developing more effective marketing strategies.

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This was developed under the guidance of Dr. Kousik Sridharan Sarathy.. The authors gratefully acknowledge his mentorship, feedback on system design, and assistance with data interpretation.