

Gazo: a standalone modularized light-weighted BCI device

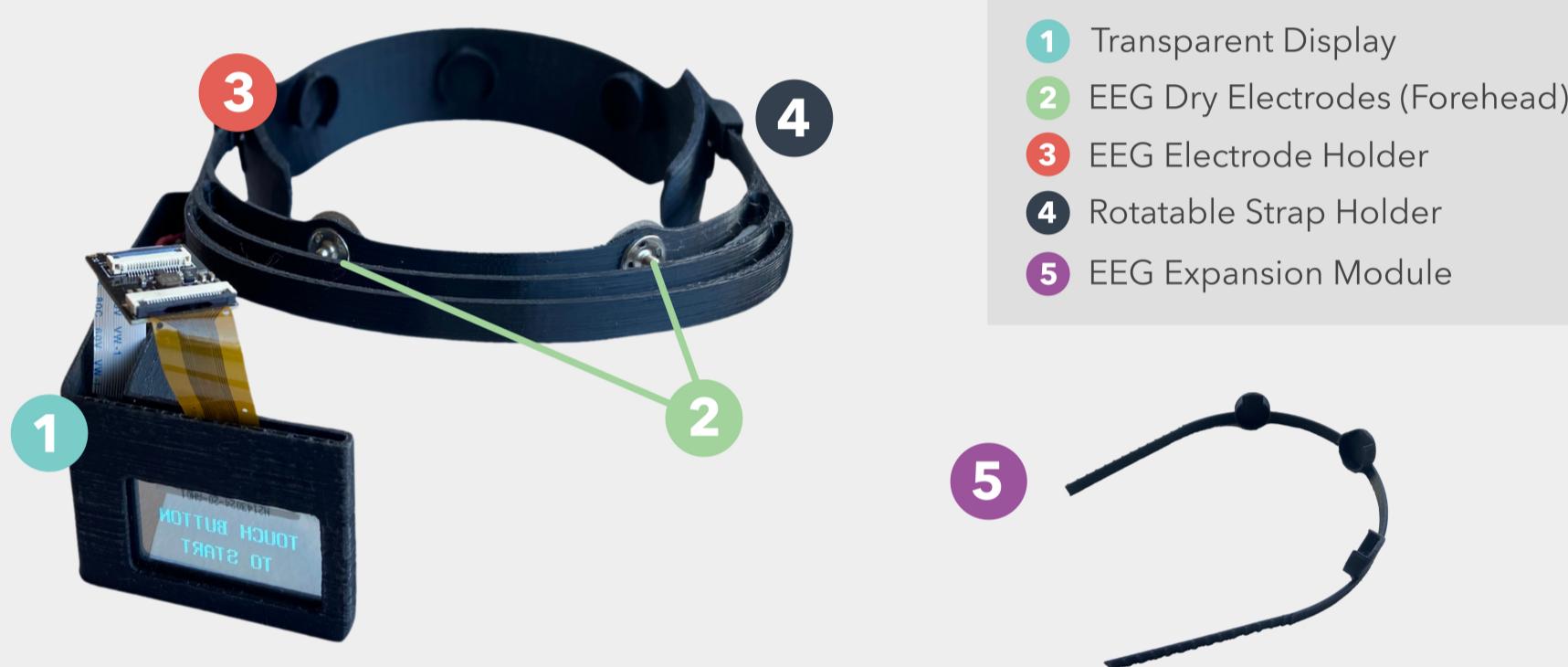
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Design

Traditional steady state visually evoked potentials (SSVEP) paradigms, which require users to gaze at a visual stimulus with both eyes, restricts its applicability in real-world scenarios. This study aims to address these limitations by:

1. Implementing visual stimulation directly on the device to ensure mobility.
2. Inducing SSVEP with minimal interference to the user's visual experience.



Gazo is a 3D-printed EEG-based BCI device that features a portable, standalone, and monocle design. Gazo, consisting of a **sensing headset** (1), a **display module** (1,2), and an **EEG expansion module** (5), is designed to accommodate a wide range of use cases that require mobile EEG capabilities.

The sensing headset itself allows 3 channels of EEGs recording located on the occipital lobe. With the expansion module applied, it can cover 3 additional channels spanning from the frontal lobe to the parietal lobe by a rotating joint.

We also proposed the transparent monocular display module as a solution to provide visual stimuli that can induce SSVEP and serve as a simple graphic user interface while **reducing the impact on vision**. The display is connected to an ESP32 board, features wireless communication via WiFi and Bluetooth, and a capacitive touch sensor.

Specifications

	EEG Channels	Weight
Transparent Display Module	Fp1, Fp2	50g
Sensing Headset	O1, Oz, O2	30g (w/o electrodes)
EEG Expansion Module	Flexible adjustment from Frontal to Parietal	10g (w/o electrodes)
Dimension: 25 x 16 x 4 cm	Battery: Lithium Polymer battery 300mAh	
Visual Stimulation Range: 0-20Hz	Charging Interface: USB Type-C	
Wireless Connection: WiFi 2.4GHz		

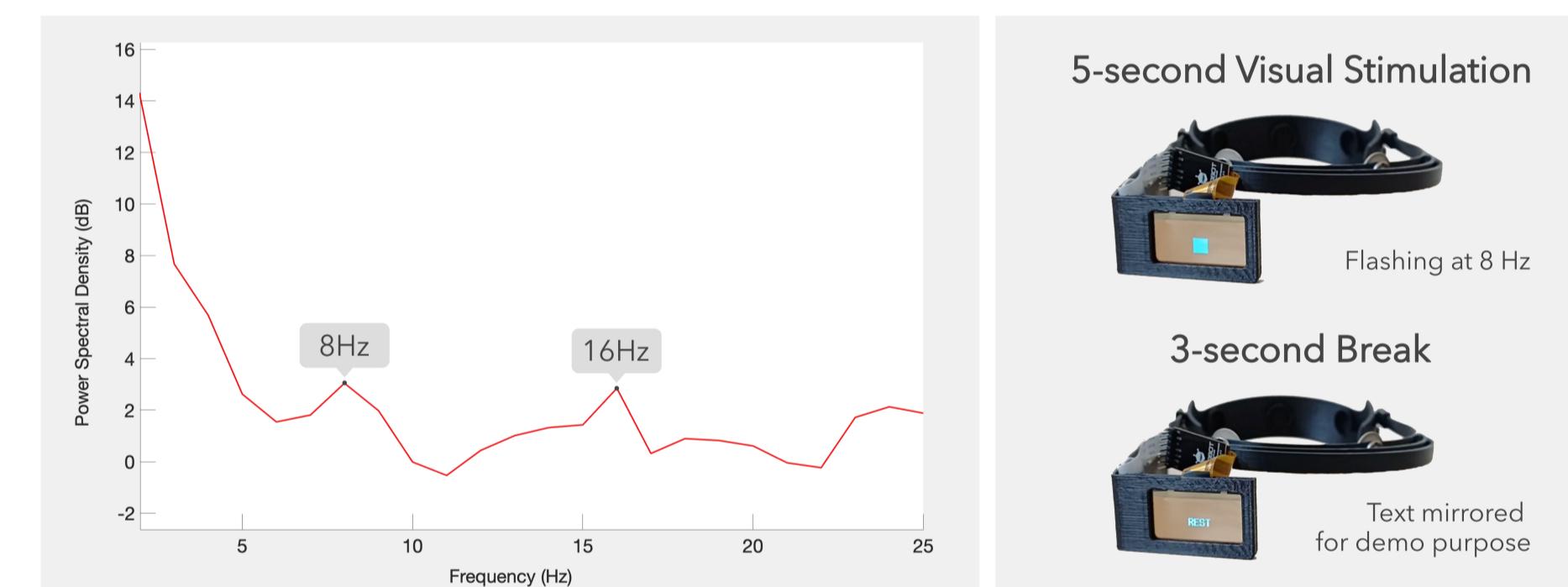
Testing

We tested Gazo through a prospective use case - the SSVEP-based person identification.

To evaluate the feasibility of a see-through SSVEP paradigm for person identification, we divided the task into two parts:

1. Testing whether SSVEP can be successfully induced using visual stimuli on the transparent display module.
2. Assessing the effectiveness of a machine learning pipeline using data from a limited number of channels for person identification.

Six participants took part in the first phase of the study. They were instructed to wear the Gazo and focus on an 8 Hz visual stimulus for five 5-second trials, with a 3-second break between each trial. The results indicated a 7.1% absolute signal-to-noise ratio (SNR) difference, corresponding to a 30.6% relative change between the stimulation and resting states, which demonstrates the feasibility of a single eyeglass-based, transparent SSVEP paradigm.



▲ The above figure presents FFT during the **8 Hz Stimulation State**. Both the fundamental frequency (8 Hz) and the second harmonic (16 Hz) peak were observed.

For the person identification machine learning pipeline, we utilized an **existing dataset** (Y. Sun et al., 2024) to build tree-based models. Using the three channels available through Gazo, we applied Canonical Correlation Analysis (CCA) and Fast Fourier Transform (FFT) to extract the features. We then trained a decision tree and a random forest model. The average false positive rate (FPR) and false negative rate (FNR) were calculated using 5-fold cross-validation across 13 subjects, showing promising performance in person identification. The decision tree model achieved an FPR of 1.73% and an FNR of 16.15%, while the random forest model improved slightly, with an FPR of 1.28% and an FNR of 13.85%.

Actual	Predicted		1690 Trials
	Non-subject	Subject	
Subject	1533	27	Each subject was compared with every other subject (including self-comparisons), across 5 trials and 2 eyes of stimulation, resulting in a total of $13 \times 13 \times 5 \times 2$ trials.
Non-subject	21	109	
DT	RF	Non-subject	Non-subject
		1540	20
Actual	Subject	Subject	Subject
Non-subject	18	112	Rejected
Non-subject	2	1	Registered subject
Non-subject	1	1	Logged in
Non-subject	1	1	Non-subject
Non-subject	1	1	Rejected
Non-subject	1	1	Registered subject
Non-subject	1	1	Logged in
Non-subject	1	1	Non-subject
Non-subject	1	1	Rejected
Non-subject	1	1	Registered subject
Non-subject	1	1	Logged in
Non-subject	1	1	Non-subject
Non-subject	1	1	Rejected
Non-subject	1	1	Registered subject
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Non-subject	1	1	Non-subject
Non-subject	1	1	Rejected
Non-subject	1</		