EasyEG: A 3D-printable Brain-Computer Interface

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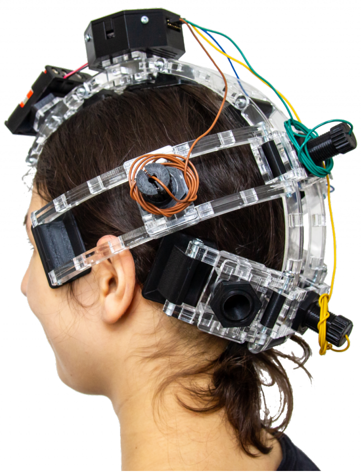
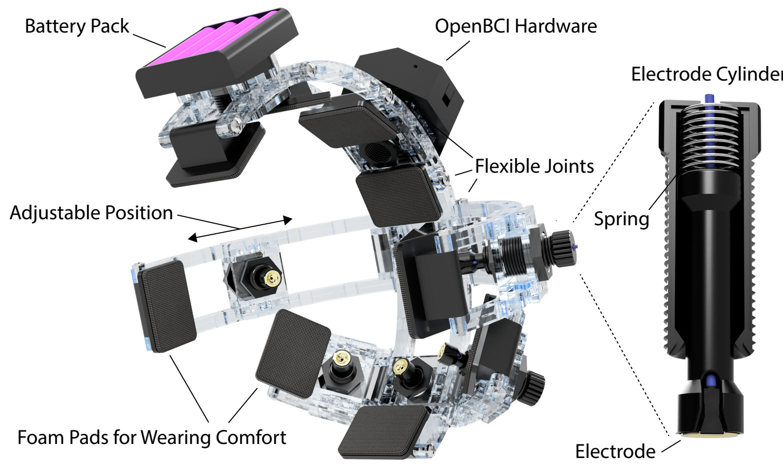


(a) User wearing the *EasyEG* headset.



(b) 3D render of *EasyEG* headset with highlighted electrode cylinder.

Figure 1: EasyEG: A Low-cost 3D-printable Brain-Computer Interface.

ABSTRACT
Brain-Computer Interfaces (BCIs) are progressively adopted by the consumer market, making them available for a variety of use-cases. However, off-the-shelf BCIs are limited in their adjustments towards individual head shapes, evaluation of scalp-electrode contact, and extension through additional sensors. This work presents *EasyEG*, a BCI headset that is adaptable to individual head shapes and offers adjustable electrode-scalp contact to improve measuring quality. *EasyEG* consists of 3D-printed and low-cost components that can be extended by additional sensing hardware, hence expanding the application domain of current BCIs. We conclude with use-cases that demonstrate the potentials of our *EasyEG* headset.

Author Keywords
Brain-Computer Interface, Electroencephalography, 3D Printing, Prototyping

CCS Concepts
•**Human-centered computing** → **Ubiquitous and mobile devices;**

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INTRODUCTION
In recent years, Brain-Computer Interfaces (BCIs) became popular in a broad range of use-cases, including interaction [4], evaluation of novel user interfaces [8], communication [6], and data visualization [9]. A central design goal of BCI headsets is a natural setup for wearing comfort and head adjustments. However, current off-the-shelf (e.g., Emotiv EPOC[1]) or medical-grade devices (e.g., Brain Products LiveAmp[2]) aim for a one-size-fits-all solution that seldomly meets the design requirements towards individual head shapes, usage complexity (i.e., headset and electrode preparation), and headset customization, such as electrode positioning or headset design for specific experiment types.

This work presents *EasyEG*, a BCI headset that can be customized for individual head shapes and use-cases using 3D printed parts. Contrary to previous available 3D-printed BCI headsets[3], *EasyEG* employs a modular design that circumvents monolithic adjustments of electrodes [2] and allows for flexible electrode positionings. Electrodes can be pushed along the scalp to measure different brain lobes through rails on the side. Nevertheless, the proposed design of *EasyEG* focuses on the evaluation of the visual cortex which is reflective for

[1]Emotiv EPOC. www.emotiv.com/epoc, last retrieved August 10, 2020
[2]LiveAmp. www.brainproducts.com/productdetails.php?id=68, last retrieved August 10, 2020
[3]Ultracortex. www.github.com/OpenBCI/Ultracortex, last retrieved August 10, 2020

the evaluation of working memory load [5, 7] that has been adopted frequently for direct [1] and indirect [3] user interaction [10]. We envision *EasyEG* as an additional step to make BCIs accessible to researchers and end-users alike. In the following, we describe the system and components, propose ideas of extending the headset, and give examples of potential use-cases that the headset enables.

SYSTEM

In this section, we describe the *EasyEG* hardware and reflect on design decisions during the construction process. All assembly instructions can be found on GitHub[4]. A depiction of the single parts is shown in Figure 1b. It consists of a flexible 3d-printed construction adjustable to the user's head and some additional low-cost components such as a processing board.

Flexible Construction of EasyEG Helmet

We integrated two aspects into our design that make the headset comfortable to wear for a broad range of users: flexible joints and adjustable electrodes.

Flexible Joints The main construction of the BCI helmet contains several joints that make it adaptable to a wide range of head forms (see Figure 1b). In total, we have nine of these joints, three in the middle arm, two in the longer arms on each side, and one in the smaller arm for each side.

Adjustable Electrodes To make the electrodes adjustable, they are attached to a height-adjustable cylinder that contains a spring on the inside. The cylinder can be screwed to adjust the height, while the electrodes are integrated in a way that avoids them to rotate. Similarly, the electrode's cable is kept on the center axis to keep it from twisting in the cylinder casing.

3D-printable and Low-cost Components

The main parts of our helmet are completely 3D-printed. Nevertheless, some additional off-the-shelf components are required, which are in sum below 300$.

The core of our BCI helmet is an *OpenBCI* board which provides the helmet with core sensing capabilities. The starting version is a *Ganglion* board with a price tag of about 250$. The board supports four channels and makes the data accessible via Bluetooth.

Additional to the board, gold cup electrodes with a diameter of 10mm are used in combination with low-impedance electrode gel for EEG measurements to ensure a good connection to the user's skin. We use foam pads attached to our 3D-printed holder to make the helmet more comfortable to wear, and we use steel springs that use 1mm thick wire formed with 12mm outer diameter and 35 mm in length in the electrode cylinders.

FUTURE WORK

In the future, we plan to extend the *EasyEG* headset with additional sensing capabilities. To achieve this, we will integrate a *NodeMCU* board that allows connecting further sensors. The board will be accessible through an API and can be reviewed through a web-based dashboard. First prototypes exist already.

Electrodes with Pressure Sensor

The electrodes that are in contact with the scalp are used to sample electrical signals from the brain. We mounted the electrodes to cylinders that point towards the scalp. Each cylinder is encapsulated by another cylinder. The encapsulating cylinder is mounted to the helmet (cf., Figure 1b). The inner cylinder can move towards the head and back. A spring inside the outer cylinder is pushing the inner cylinder towards the scalp. This allows applying pressure towards the head for better contact and to adapt to different head sizes. Pressure sensors inside the cylinders attached to the spring can be used to detect if the BCI is properly mounted.

Correct Positioning Through Gyroscope

To ensure the correct positioning of the interface on the user's head, we use a gyroscope. Through the gyroscope, we can detect if the helmet is centered on the user's head. When the helmet slides of to one side, the user or experimenter is warned that the helmet's position must be corrected.

ENVISIONED USE-CASES

The overall aim of *EasyEG* is to provide a seamless BCI setup. For the headset, we envision the following use-cases.

Seamless Setup and Customization

EasyEG bypasses complex BCI setups by providing flexible adjustments that adapt to the user's head shape. *EasyEG* is highly adjustable and can be used in several application contexts that otherwise would affect social acceptance, data quality, or usage in specific application contexts, such as the evaluation of cortical activity in augmented or virtual reality.

Remote Studies

BCI headsets that are used in experiments need additional verification by the experimenter to guarantee clean data collection, rendering these headsets unsuitable for remote studies. *EasyEG* can be extended by additional sensors (i.e., pressure sensors) that allow for adjustments towards the participant's head shape. Furthermore, the electrode-scalp contact can be verified by the experimenter remotely. Here, data quality can be surveilled in combination with the electrode impedance and obtained electrode pressure.

CONCLUSION

This works presents *EasyEG*, a low-cost brain-computer interface that allows for rapid prototyping in research projects. Due to the high flexibility, the device is suited to be used regardless of the size and shape of the user's head. Electrodes can be positioned on the rails of the headset to provide flexible measurements from different brain areas. Here, *EasyEG* strives for a user-friendly design that makes BCI applications more accessible for end-users and researchers. We suggest a variety of possible sensing capabilities that can be of use if non-experts use the device or experts guide novices remotely for future versions of *EasyEG*. We anticipate a higher adoption of BCI research experiments and use-cases with *EasyEG*, since the BCI is set up properly to sample brain signals reliably and accurately. Therefore, we plan to extend *EasyEG* with an API to remotely access and visualize sensory data.

[4] *EasyEG* on GitHub. https://github.com/johnny1a679/EasyEG, last retrieved August 10, 2020

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