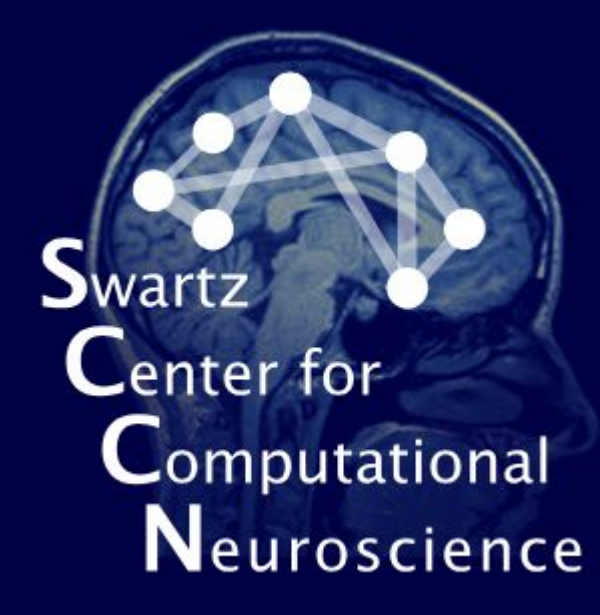




Team 8: Design of a Modular Electroencephalography Headset with Hydrogel-Based Electrodes

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Mentors: Dr. Gert Cauwenberghs, Dr. Tzyy-Ping Jung, Yuhong Zhang



BACKGROUND

- Electroencephalography (EEG) is non-invasive device that measures brain activity and function by placing electrodes on the scalp
- Current EEG systems have tradeoffs and limitations

Wet EEG	Dry EEG
<ul style="list-style-type: none"> Messy gel Long setup times 	<ul style="list-style-type: none"> High Impedance >1 MΩ User Discomfort
<ul style="list-style-type: none"> Fixed electrode configurations & headset sizes Expensive 	

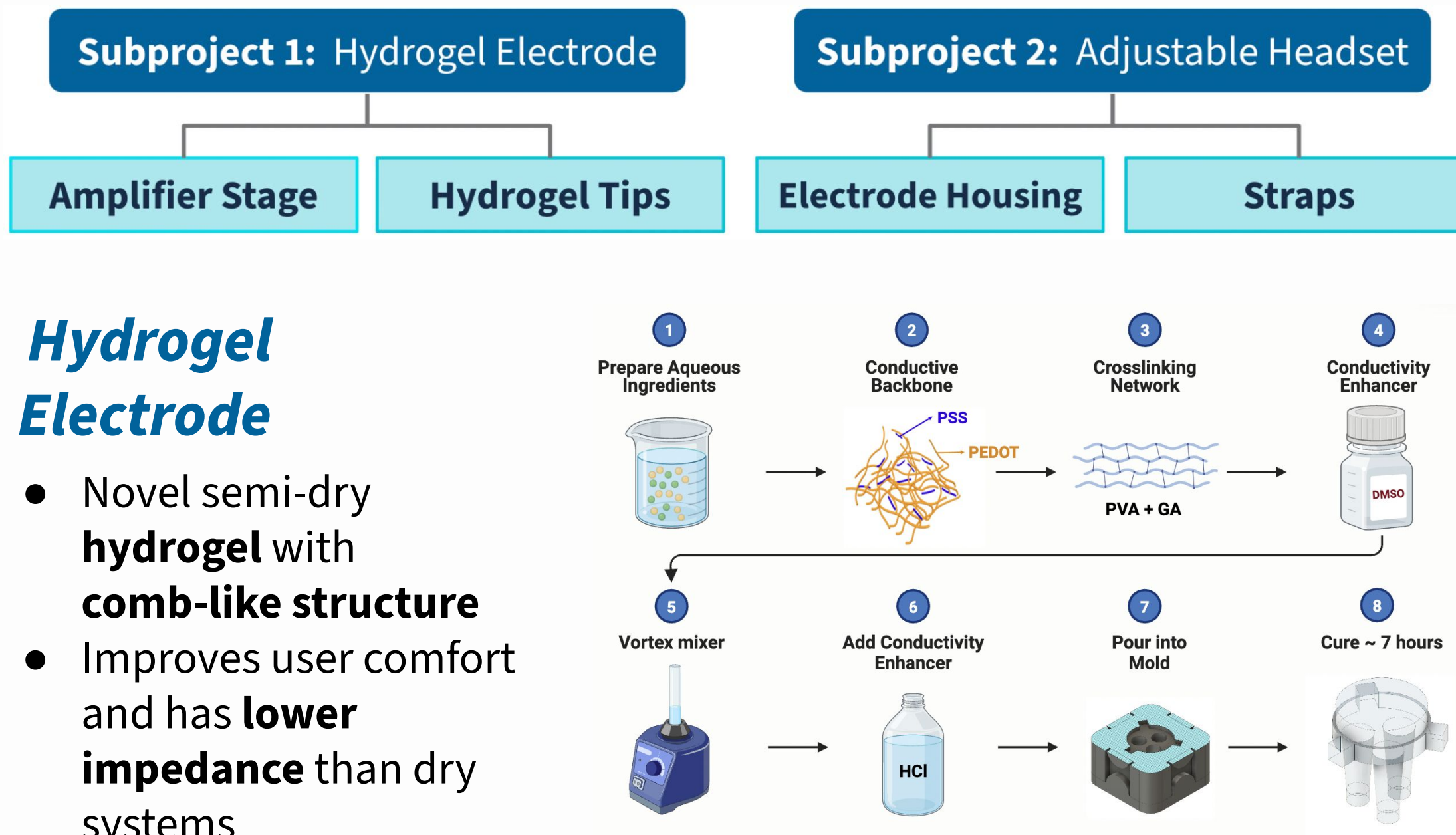
Problem

Current EEG systems have tradeoffs in signal quality and usability. Furthermore, high costs and fixed electrode layouts make EEG less accessible and less adaptable to different users.

Design Goals

Low Input Impedance <40 kΩ	System Modularity Adjustable sizing and configurations	Comfort & Ease of Use ~10 min setup
		Low-Cost & Accessible <\$400

PROPOSED SOLUTION



Adjustable Headset

- Modularity** for different electrode configurations and head sizes
- Easy, **quick setup**, accessible, and **affordable**

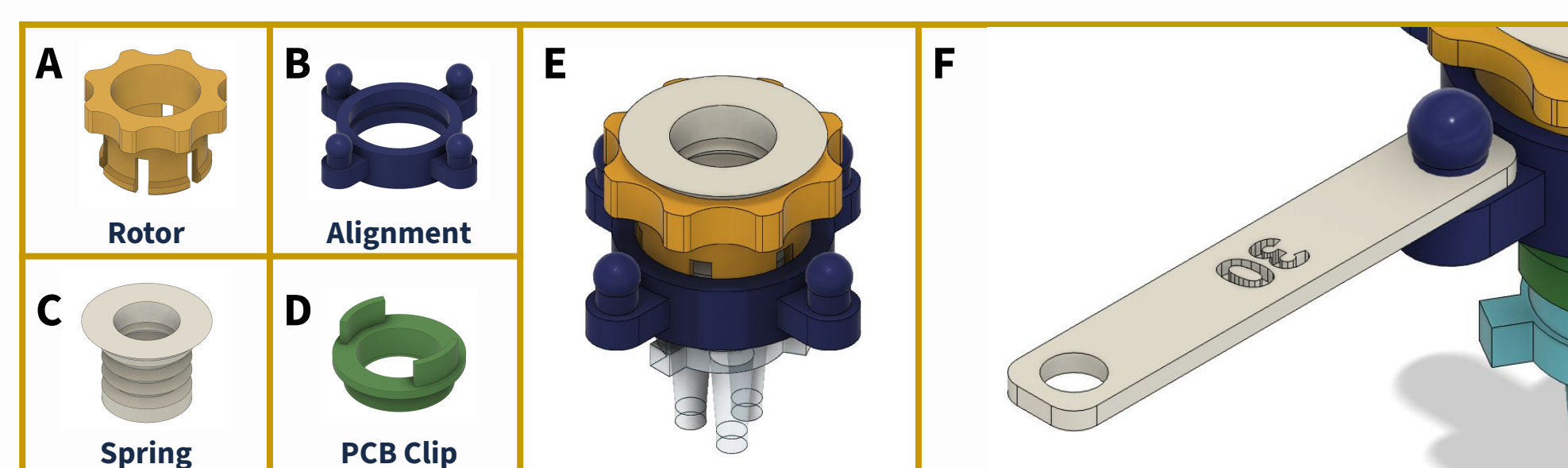


Figure 1: (A, B, C, D) Subcomponents of the (E) electrode housing assembly and (F) a sample TPU strap connection

METHODS & RESULTS

Subproject 1 - Hydrogel Electrode

- Hydrogel synthesis successful
 - Final formula consists of **PEDOT:PSS, PVA, HCl, GA, and DMSO**
- Final mold developed
 - Three-comb configuration for structural integrity
- Skin electrode impedance achieved
 - Measured **30kΩ**, achieving target specifications
- Structural integrity and impedance stability over time
 - Comb morphology and stability maintained for 5 days
- PCB integration
 - Silver epoxy used to bond hydrogel to PCB copper pad
 - PCB performance tested with CGX dry electrodes

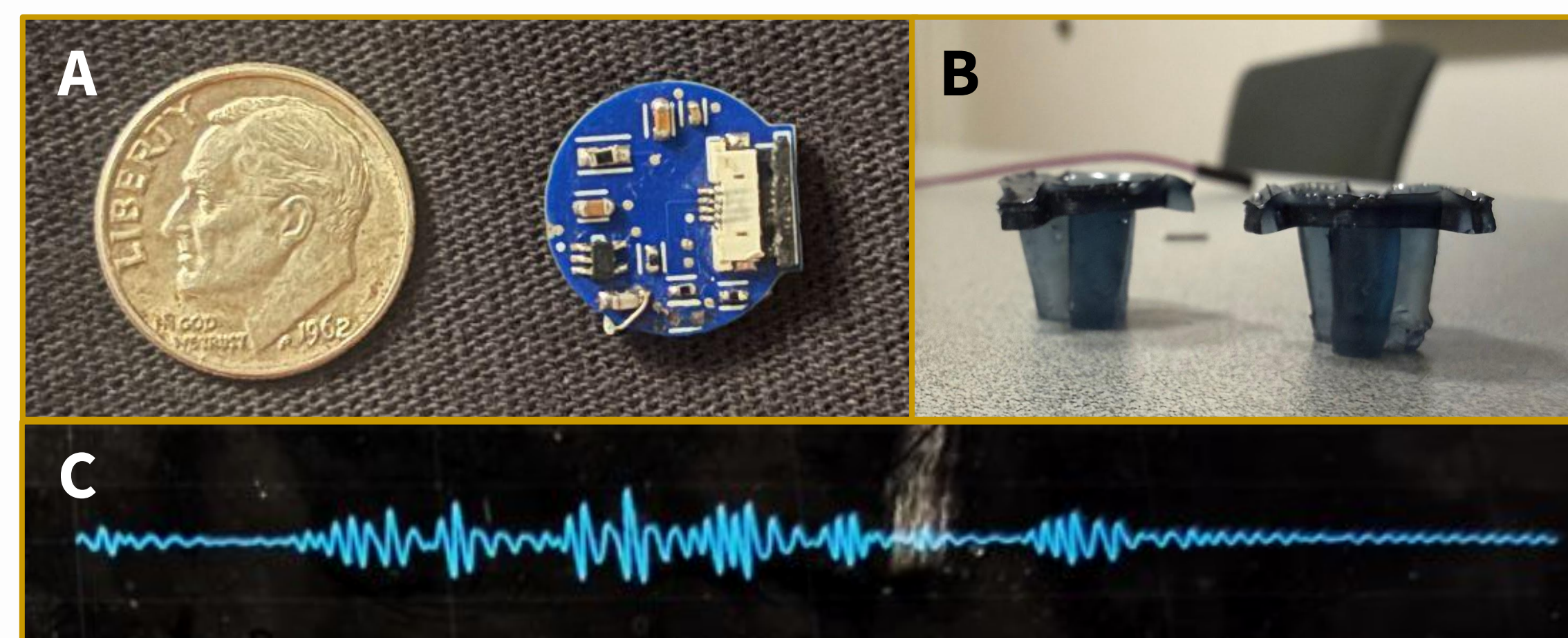


Figure 2: (A) Preprocessing PCB printed to scale, (B) cured hydrogel electrode tips and (C) recorded alpha waveforms from PCB testing with dry electrode

Subproject 2 - Adjustable Headset

- Developed prototypes of headset components
 - Tested interchangeable headstrap sizes on different head circumferences
- Electrode mount able to adjust position while remaining intact
 - Effective ROM relative to normal axis
- Assessed for comfort during real-world fit testing
 - Increased user-reported comfort relative to existing dry EEG headsets
- Evaluated electrode spring compliance and bulb connection ease of insertion/removal

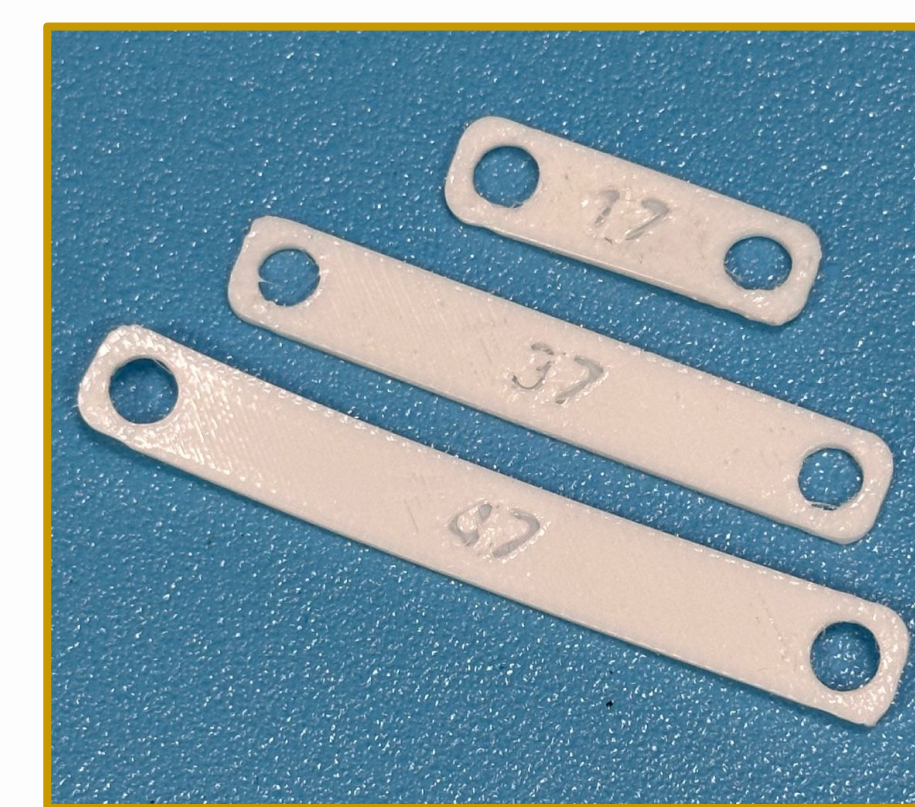


Figure 3: Different-sized TPU straps to connect adjacent electrode housings.

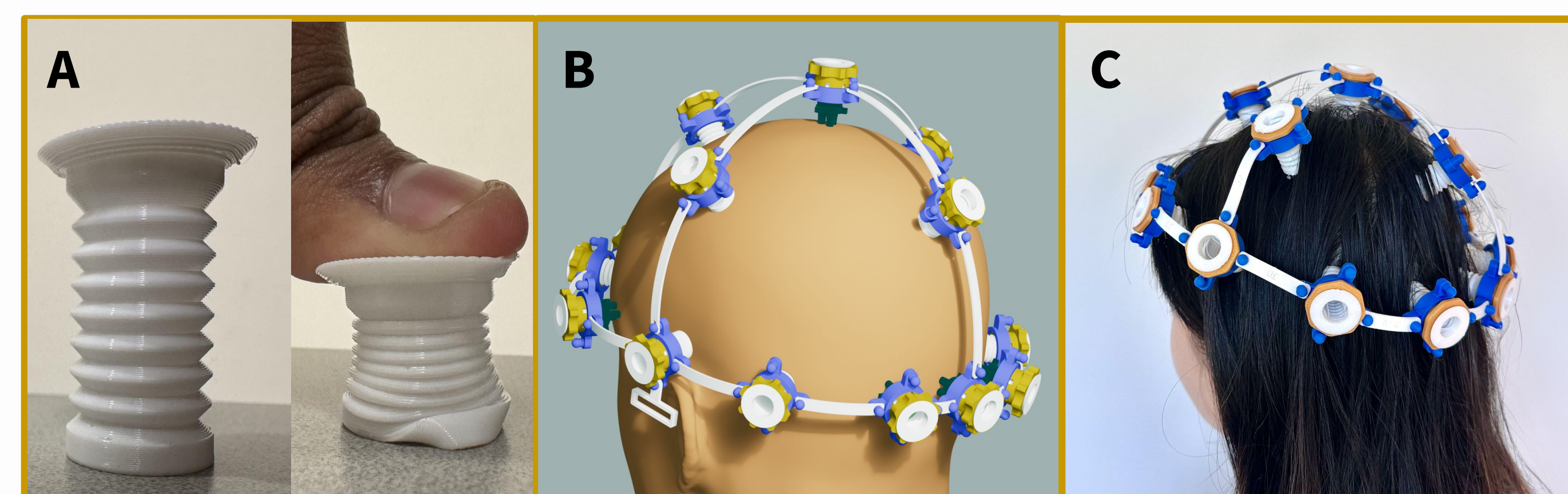


Figure 4: (A) Relaxed vs. compressed flexible placeholders (B) full digital reconstruction of the headset with both hydrogel and placeholders (C) physical headset on subject with only placeholder electrodes.

DISCUSSION

Measurement	Target Value	Calculated Value	Result
Impedance	10 kΩ (ideal)	30kΩ	Meets IEC requirements
Setup Time	<15 minutes	~10 minutes	Far below wet EEG setup time (~30 mins)
Total Cost	\$400	<\$250	Far below existing market costs (upwards of \$10,000)

Principal Limitations

- The hydrogel electrode has not yet been integrated with the PCB: The claimed semi-dry performance advantage has not been empirically confirmed.
- Circuit exhibits an undesirable transient response
- No combined impedance, signal quality, or comfort data are yet available: This requires full system integration – would test in the next project cycle.
- Headstraps do not offer sufficient compressive loading

IMPACT & FUTURE DIRECTIONS

- Hydrogel-based EEG electrode with comb morphology is novel in its development
- Adjustable 3D-printable EEG headsets provide accessible technology to tinkerers and educators

Next Steps

- Full-system test + signal validation
- Improve compression on headstraps
- Identify origin of transient response

Long-Term

- Map full 10-20 positions with current parts
- Test under different conditions (e.g., walking)
- Assess commercial viability of subprojects

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References →

