EEG System Evaluation Protocol

Objective: To systematically evaluate EEG systems devices for purchase based on predefined criteria.

Preparation Phase

Device Selection

- Select top two devices from the assessment matrix for in-person evaluation.
  - High Density EEG system: g.tec Nautilus Multi-Purpose vs Brain Products actiCap Xpress Twist + LiveAmp vs Wearable Sensing DSI-24
  - Low Density EEG system: OpenBCI Ultracortex vs g.tec Unicorn Hybrid vs g.tec Nautilus Multi-Purpose

Setup Arrangements

- Secure rental or demo units of the selected devices, ensuring all necessary components are included.
  - High Density EEG system: g.tec Nautilus Multi-Purpose vs Brain Products actiCap Xpress Twist + LiveAmp vs Wearable Sensing DSI-24
  - Low Density EEG system: OpenBCI Ultracortex vs g.tec Unicorn Hybrid vs g.tec Nautilus Multi-Purpose

Test Environment

- Set up a controlled test environment that simulates typical use scenarios.

Testing Phase

- Channels:
- Setup time:
- Fit and Comfort Analysis: Wear device for extended period; assess ergonomics and child adaptability.
- Compatibility and Integration Testing: Examine integration with existing systems, focus on LSL support.
- Physiology:

Final Evaluation and Decision

Decision Meeting

- Review testing results with stakeholders and make a final purchase decision.

Documentation

- Document the testing process, results, and decision rationale for future reference.

Preparation Phase

RG1a. High-Density Dry EEG System

In response to NF6 indicating dissatisfaction with the setup times for high-density wet EEG systems, a new high-density dry EEG system shall be purchased. A systematic evaluation of potential solutions shall be conducted prior to purchase. Initial contenders will be evaluated based on their aggregate suitability score, indicated in Table 4.

RG1b. Low-Density Dry EEG System

In response to NF1 indicating dissatisfaction with the Emotiv EPOC X low-density dry EEG system, a new low-density dry EEG system shall be purchased. A systematic evaluation of potential solutions shall be conducted prior to purchase. Initial contenders will be evaluated based on their aggregate suitability score, indicated in Table 4.

Table 1: Assessment matrix for wearable eye tracking solutions

Criteria for High-density EEG systems	**Weights**	**Criteria for Low-density EEG systems**	**Weights**
Cost	2	Cost	2
Channels	6	Channels	2
Fit	3	Fit	3
Setup	3	Setup	3
Compatibility	5	Compatibility	5
Physiology	1	Physiology	1
Total Score	-	Total Score	-
1 = not important; 6 = extremely important			

Criteria scoring for High-Density EEG system shall be based on the following parameters:

- Cost:
    - 1 below expectations >25K
    - 2 meets expectations 15K - 25K
    - 3 exceeds expectations <15K
- Channels
    - 1 below expectations <18
    - 2 meets expectations 18 - 32
    - 3 exceeds expectations >32
- Fit

    - 1 below expectations >12 yo
    - 2 meets expectations any other
    - 3 exceeds expectations <9 yo
- Setup
    - 1 below expectations >25 min
    - 2 meets expectations any other
    - 3 exceeds expectations <10 min
- Compatibility
    - 1 below expectations no LSL integration
    - 2 meets expectations community-developed LSL integration
    - 3 exceeds expectations mfr-supported LSL integrations
- Physiology
    - 1 below expectations no mfr physio signal acquisition box
    - 2 meets expectations mfr physio signal acquisition box but not mfr sensors
    - 3 exceeds expectations mfr physio signal acquisition box and sensors

Criteria scoring for Low-Density EEG system shall be based on the following parameters:

- Cost:
    - 1 below expectations > 3K
    - 2 meets expectations 1k - 3k
    - 3 exceeds expectations < $1k
- Channels
    - 1 below expectations <5 channels
    - 2 meets expectations 5 - 12
    - 3 exceeds expectations >12 channels
- Fit
    - 1 below expectations >12 yo
    - 2 meets expectations 9-12
    - 3 exceeds expectations <9yo
- Setup
    - 1 below expectations > 25 mins
    - 2 meets expectations 10-25 mins
    - 3 exceeds expectations <10 mins
- Compatibility
    - 1 below expectations no LSL integration
    - 2 meets expectations community-developed LSL integration
    - 3 exceeds expectations mfr-supported LSL integrations
- Physiology
    - 1 below expectations no mfr physio signal acquisition box
    - 2 meets expectations mfr physio signal acquisition box but not mfr sensors
    - 3 exceeds expectations mfr physio signal acquisition box and sensors

Total score shall be obtained by summation of each solution's individual criteria scores multiplied by the corresponding weight. Higher score is desirable.

Two candidates shall be selected for further in-person evaluation via rental or demo program. A quantitative and repeatable evaluation methodology shall be utilized to assess the strengths and weaknesses of the device with respect to data acquired.

Table2: High-Density EEG systems (pts)

Set 1

Criteria	Weight	CGX Quick-20r v2	Wearable Sensing DSI-24	Brain Products actiCap Xpress Twist + LiveAmp	mBrainTrain Smarting Pro X (Semi Dry)	g.tec Nautilus Multi-Purpose
Cost	2	1	2	1.6	2	1
Channels	6	2	2	2	3	3
Fit	3	2	3	3	2	3
Setup	3	2	3	3	2	2
Compatibility	5	2	2	2	2	2
Physiology	1	3	1	3	3	3
Total Score		39	45	47	47	48
1 = below expectations; 2 = meets expectations; 3 = exceeds expectations						

Rejected Devices - Reason given in Table 3

Table 3: High-Density EEG Systems(details)

Set 1

Criteria	CGX Quick-20r v2	Wearable Sensing DSI-24	Brain Products actiCap Xpress Twist + LiveAmp	mBrainTrain Smarting Pro X (Semi Dry)	g.tec Nautilus Multi-Purpose
Cost	$21,880 (acc to wireless eeg paper) $22,800 (on applied neuroscience)	$24,800 https://bio-medical.com/dsi-24-wearable-sensing-eeg-headset-w-neuroguide-gold-bundle.html	~ $35K	PRO - $20K	For 8 channels $6556.36 For 16 channels $13,126.29 For 32 channels $22,323.81
Channels	21	21	8, 16 or 32	64	8,16 or 32
Fit	Head size 52-62 cm Wgt 526 g	Adult version: 52-62 cm Child version: 48-54 cm	Cap sizes range from infants to adults		Mini, midi, maxi options 32 - 48 cm
Setup		< 3 mins	< 3 mins	< 10 mins	
Compatibility	LSL compatible	LSL compatible	LSL compatible	LSL Compatible	LSL compatible
Physiology	AIM https://www.cgxsystems.com/auxiliary-input-module-gen2		Sensor & Trigger extension (STE) for LiveAmp https://www.brainproducts.com/solutions/liveamp-ste/		
Sensor	Drypad, Flex	Separate devices for sensors	https://www.brainproducts.com/solutions/sensors/		g.SENSORS https://www.gtec.at/product/body-sensors/

		https://wearablesensing.com/multimodal-2/			
Softwares				mBrainTrain Streamer	
Other Comments	**Rejected -** low assessment score First cost converted from euros Applied neuroscience : https://appliedneuroscience.com/product/cgx-quick-20r-collection/ https://www.cgxsystems.com/_files/ugd/ed2c7a_5f4335301e644e0d98a33f91f61bc36c.pdf	Cost given for a bundle https://wearablesensing.com/wp-content/uploads/2021/12/Wearable-Sensing-DSI-24-Specification-Sheet_s.pdf	https://pressrelease.brainproducts.com/twist/	https://soterixmedical.com/research/mobile-eeg/smarting-pro-line	**Rejected -** Call with Sales was not informative Link to get device demo: https://www.gtec.at/contact/ Fit: https://www.gtec.at/product/g-sahara-hybrid-eeg-electrodes/

Table 4: Low-Density EEG systems (pts)

Criteria	Weight	Muse 2	OpenBCI Ultracortex	Bitbrain Air	Neurosity Crown	g.tec Unicorn Hybrid
Cost	2	3	3	1	2	2
Channels	2	1	3	2	2	2
Fit	3	3	3	2	3	3
Setup	3	2	3	3	3	2
Compatibility	5	2	2	2	2	2
Physiology	1	1	2	1	1	3
Total Score		34	42	32	37	36
1 = below expectations; 2 = meets expectations; 3 = exceeds expectations						

Table 5: Low-Density EEG systems (details)

Criteria	Muse 2	OpenBCI Ultracortex	Bitbrain Air	Neurosity Crown	g.tec Unicorn Hybrid
Cost	$249.99	$399.99 - $1149.99	$5470.02	$999	$1183.00
Channels	4	8 or 16	8	8	8
Fit	30 - 35 cm, designed to sit around your forehead to the back of each ear.	Small = 42 - 50 cm Medium = 48 - 58 cm Large = 58 - 65 cm	53 - 61 cm	One size fits all	Small 50-54cm Medium 54-58cm Large 58-62cm
Setup	10-25 mins	<30s	< 2 mins		Couple of mins
Compatibility	LSL compatible	LSL compatible https://docs.openbci.com/Software/CompatibleThirdPartySoftware/LSL/	LSL compatible	LSL compatible	LSL compatible
Physiology		All-in-one emobit bundle	Versatile bio https://www.bitbrain.com/neurotechnology-products/biosignals/versatile-bio		
Sensor				2 haptic motors Motion detecting accelerometer	g.Sensors https://www.gtec.at/product/body-sensors/
Softwares					
Other Comments	https://choosemuse.com/produc	3 purchasing options	Cost converted from euros,	https://neurosity.co/crown	https://www.gtec.at/unicorn

	ts/muse-2 https://choosemuse.my.site.com/s/topic/0TO41000000Wo98GAC/getting-started?language=en_US	https://shop.openbci.com/products/ultracortex-mark-iv Setup video in link above Physiology: https://shop.openbci.com/products/all-in-one-emotibit-bundle?_pos=1&_sid=c8dea1629&_ss=r	channels (Wireless EEG paper) chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://cdn.bitbrain.com/docs/2023/MinimalEgg-Air-Brochure.pdf https://www.bitbrain.com/neurotechnology-products/dry-eeg/air		-faqs/ https://www.gtec.at/product/body-sensors/
1 = below expectations; 2 = meets expectations; 3 = exceeds expectations					

Data Modality	**Hardware**	**Notes**
EEG	PC1 (Windows laptop) Monitor (For tasks) KBM Cabling (Homemade TTL)	

Comprehensive Testing Protocol Overview

Our protocol is structured to facilitate a thorough evaluation of the EEG devices (High-density and low-density), ensuring a multifaceted analysis of their performance, usability, and integration capabilities. The procedure is delineated into distinct phases, each tailored to assess specific aspects of device functionality and user interaction. At the conclusion of each phase, we will declare a "winner" for the specific criterion based on our findings or identify a "tie" if the devices perform equivalently. This comparative approach will allow us to ascertain the strengths and weaknesses of each device in a direct manner.

Quantitative Evaluation

Calibration Time Assessment: Conduct a swift calibration for each participant in accordance with manufacturer stipulations. The primary objective of this phase is to quantify the setup time, providing insights into the device's ease of initiation.

Signal Quality Evaluation: Implement tasks (eyes open/eyes closed, SSVEP and motor evoked potential) with increasing robustness and compare signal quality of devices with quality of data collected using EGI device

Compatibility and Integration Testing: Examine the device's compatibility with existing technological ecosystems, with a special emphasis on its integration capabilities with the Lab Streaming Layer (LSL). This assessment aims to identify potential challenges and opportunities in deploying the device within established research or clinical frameworks.

Qualitative Assessment

Fit and Comfort Analysis: Instruct participants to use the wearable device for a prolonged duration, encouraging them to perform a series of activities that test the device's ergonomics. Feedback on the comfort, fit, and adaptability, particularly concerning child users, will be systematically gathered.

User Experience Survey: Post-testing, collect comprehensive feedback from participants regarding their subjective experience with the device, focusing on usability and comfort.

Initial Device Selection

1. Wearable Sensing DSI-24
2. mBrainTrain Smarting Pro X (Semi Dry)
3. Brain Products actiCap Xpress Twist + LiveAmp
   [Brain Products actiCap Xpress Twist + LiveAmp eliminated from trial list - delay in delivery of device as a result of issues on sales end]

Devices acquired for demo/trial

1. Wearable Sensing DSI-24
2. mBrainTrain Smarting Pro X (Semi Dry)

Testing Results (High-Density EEG systems)

Wearable Sensing DSI-24 **vs** mBrainTrain Smarting Pro X (Semi Dry)

Quantitative Evaluation

Protocol:

1. Resting State
2. Evaluating alpha activity
3. Motion artefacts

    3 mins eyes closed and 3 mins eyes open
    Evaluation videos

Fit and Comfort Analysis:

Head size evaluation
Set up process
Wear time

Qualitative Assessment

User Experience Survey:

1. Prior experience with EEG
2. Comfort level during set-up process
3. Comfort level during data collection

Compatibility and Integration Testing:

Testing Results (Low-Density EEG systems)

Quantitative Evaluation

Protocol:

1. Resting State
2. Steady State Visual Evoked Potentials (SSVEP)
   A flickering lights on a screen at a specific frequency
3. Flanker Test

Fit and Comfort Analysis:

Qualitative Assessment

User Experience Survey:

Compatibility and Integration Testing:

Links to devices

1. Response time box: https://lobes.osu.edu/rt-box.php

2. High-density EEG devices:
    a. Brain Products actiCap Xpress Twist + LiveAmp
    b. g.tec Nautilus Multi-Purpose
    c. Wearable Sensing DSI-24

3. Low-density EEG devices:
    a. OpenBCI Ultracortex
    b. g.tec Unicorn Hybrid

4. Grippy Trigger/ Action device: DIY it

References

1. Wireless EEG: A survey of systems and studies
   https://www.sciencedirect.com/science/article/pii/S1053811922008953
2. https://www.cdc.gov/growthcharts/html_charts/hcageinf.htm
3.