Human Rights in the Age of Neurotechnology: Impact, Risks and Opportunities

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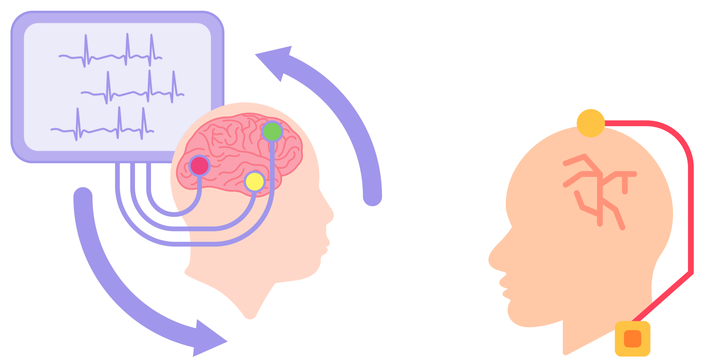
Background: Neurotechnology advances are expanding the range of people impacted by their use, and the degree of insights gathered from neural data is growing exponentially due to AI. Consequently, the UN Human Rights Commission called for input on the existing Universal Declaration of Human Rights (UHDR), including proposals for novel rights in the face of these advances.

Objective: Through the lens of universal human rights, identify risks and opportunities posed by emerging neurotechnology.



Primary Impact on Human Rights by Neurotechnology

Cognitive Liberty: the right to self-determination over one's own brain and mental experiences, and to be free from mental interference, manipulation, or coercion by others.

Article 3: Right to life, liberty, and security of person

Risk: Neural manipulation could diminish autonomy
Opportunity: Enhanced cognitive functions and mental health treatments

Article 12: Right to freedom from arbitrary interference with his privacy; right to the protection of the law against such interference or attacks

Risk: Infringement of mental privacy
Opportunity: Advanced data protection frameworks

Article 18: Right to freedom of thought, conscience, belief, and religion

Risk: Potential manipulation of thoughts and beliefs
Opportunity: Stronger protections for mental freedom

Secondary Impact on Human Rights by Neurotechnology

Article 25: Right to adequate living (food, water, energy, healthcare), protections for vulnerable populations, security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond one's control

Risk: Potential health issues from neurotechnology failure
Opportunity: Improved healthcare outcomes and support for vulnerable populations

Article 7: Right to equality and equal protections before the law without discrimination

Risk: Discrimination based on neural data
Opportunity: Equal access to cognitive enhancements

Article 23: Right to freedom to work, choice of work, without interference and with equal protections and remuneration

Risk: Workplace discrimination based on neural data
Opportunity: Enhanced productivity and job performance

Article 4: No one shall be held in slavery or servitude

Risk: New forms of inequality for neurotechnology users
Opportunity: Increased independence through cognitive enhancements

Article 19: Right to freedom of opinion and expression; the right to hold opinions without interference and to seek, receive and impart information and ideas through any media and regardless of frontiers

Risk: Coercion of thoughts through neuromodulation
Opportunity: New forms of communication and expression

Article 26: Right to education, right to full development of the human personality, tolerance

Risk: Educational discrimination based on neural data
Opportunity: Personalized learning and cognitive support

Call to Action: Healthcare Professionals

- Policy advocacy to help shape regulations that protect patient rights while fostering innovation in neurotechnology
- Stringent cybersecurity protocol implementation to safeguard neural data from unauthorized access and potential misuse
- Clear, accessible, informed consent processes to ensure patients fully understand the implications of interventions
- Uphold medical ethics standards in use of neurotechnologies, ensuring that patients are benefitted without infringing upon their rights
- Adherence to policies that ensure equitable access of neurotechnology for patients

Call to Action: Developers

- Adoption of cybersecurity standards accepted by the broader industry to protect end users from data breaches and device hacking
- Validation or certification of brain data decoding methods to prevent inaccurate or overly broad interpretation of data that may be misused and violate rights related to prosecution, employment and education
- Awareness of consumer rights to revoke consent for data use, resale, and storage
- Understanding of regulations to protect vulnerable populations that are clearly defined and actionable

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Transcranial Photobiomodulation Control System Compatible with EEG

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Rationale: Transcranial Photobiomodulation (tPBM) is an experimental treatment for brain disorders and neurodegenerative diseases. Near infrared (NIR) light applied to the surface of the head targets underlying brain and vascular tissue to promote energy production, modulate inflammation, and trigger local vasodilation. These may be the mechanisms of action for tPBM treatments. A putative mechanism of neural frequency entrainment may drive direct effects on cognitive function. Simultaneous electroencephalography (EEG) recording during tPBM could evaluate potential mechanisms of NIR stimulation.

Objective: A hybrid EEG-tPBM device and control system was designed to study the direct effects of tPBM on the brain.

Board Design

Objective: Interchangeable, modular panels to be fitted on a headworn frame for selective surface coverage and dry electrode placement; granular control of LED arrays for protocol specificity.
Board dimensions: 4.4 x 3.2 cm boards of 36 diodes in a 6 x 6 array; 850nm and 1070nm diode panels
Power Management: Variable AC power for heat standards and requirements for different LEDs
Mounting: Elastic 4-point mounting between electrodes on an OpenBCI Ultracortex IV Frame; 1 to 11 panel arrangements; 8 or 16 electrode montage; diodes are 5-10 mm from scalp

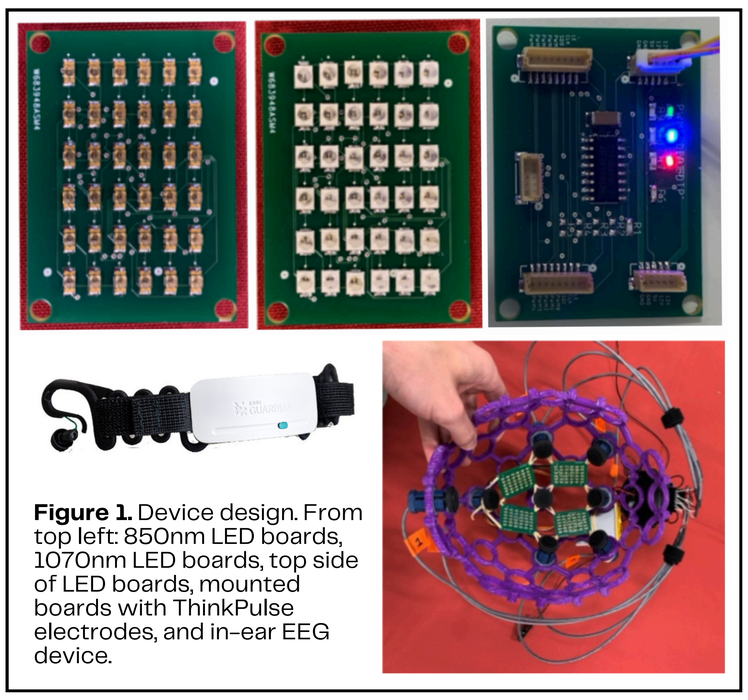

Figure 1. Device design. From top left: 850nm LED boards, 1070nm LED boards, top side of LED boards, mounted boards with ThinkPulse electrodes, and in-ear EEG device.

Control System

Objective: Simple user interface for protocol parameter prescription and potential for closed loop inputs
Control parameters: Unit control of 6 diodes; set duty cycle, frequency, duration, stimulation pattern; activation of select panels
Interface: Touchscreen GUI for parameter inputs and protocols
Programming: Protocol variable settings sent to boards via Arduino

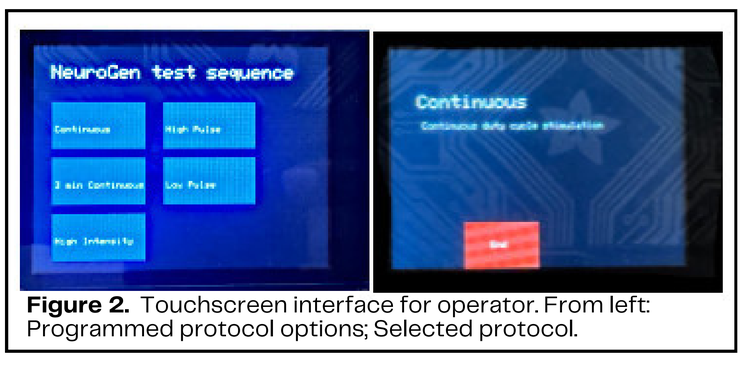

Figure 2. Touchscreen interface for operator. From left: Programmed protocol options; Selected protocol.

EEG Device Compatibility

Objective: Select an EEG device that provides clean signal and sensitive to candidate frequency-based metric
Signal Quality: Closely positioned electrodes show harmonic interference from pulsed electrical activity; in-ear distal electrodes show no interference
Sensitivity: In-ear electrode shows greater sensitivity and lower overall noise

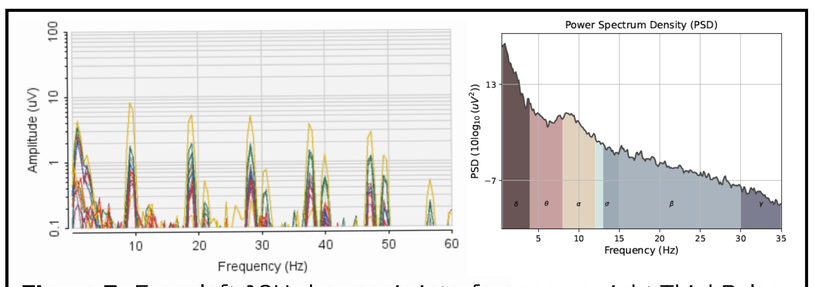

Figure 3. From left: 10Hz harmonic interference on eight ThinkPulse electrodes; No 10Hz harmonic interference on single channel in-ear EEG.

Preliminary Results

Objective: Demonstrate frequency entrainment in in-ear EEG by tPBM and compare to validated cognitive tests
Stress Test: Increased cognitive load decreased alpha power, validating in-ear EEG sensitivity
tPBM: Pulsed protocol at maximal intensity and duration did not show hypothesized entrainment signal of theta power enhancement

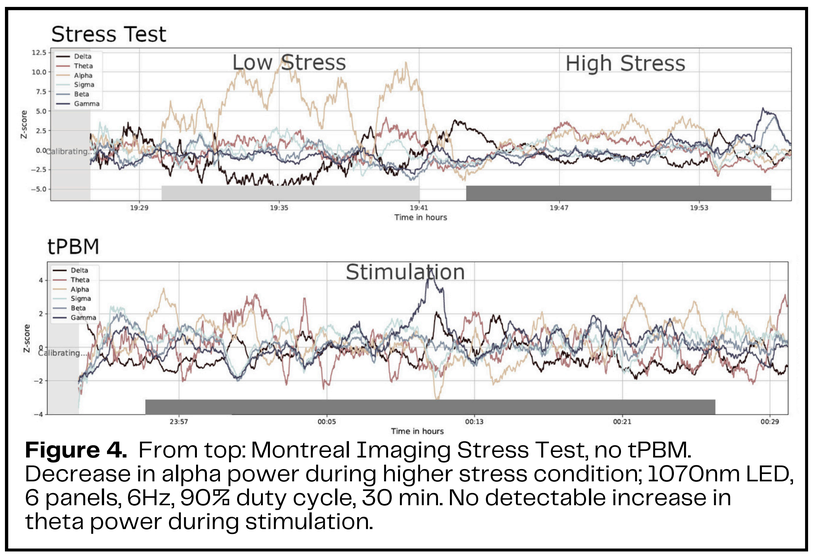

Figure 4. From top: Montreal Imaging Stress Test, no tPBM. Decrease in alpha power during higher stress condition; 1070nm LED, 6 panels, 6Hz, 90% duty cycle, 30 min. No detectable increase in theta power during stimulation.

Discussion

Conclusion: Insufficient fluence is reached with the current prototype and protocol
Effective Dosage: An estimated 2-4 J/cm^2 elicits a response from neurons; fluence from LED source is 85/144 J/cm^2 (1070 /850 nm) and the >99% attenuation results in <1 J/cm^2 reaching the brain
Future Directions: Increase fluence for greater effective dose and surface area to confirm sufficient stimulation for EEG metric validation

Broader Vision: Design a closed-loop tPBM system responsive to brain activity metrics

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Designand Validation of EEG Biomarkers for Transcranial Photobiomodulation

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Rationale: Transcranial photobiomodulation (tPBM) delivers near infrared (NIR) light to enhance cellular energy production, immune responses, circulation and brain function due to disease or injury. Yet real time and validated electrophysiological biomarkers associated with tPBM are absent, which impairs practitioner ability to design efficacious tPBM protocols. Studies of low level laser therapy (LLLT) show changes is global frequency and network EEG metrics, but LED devices have not been validated.

Objective: Evaluate candidate EEG biomarkers for an LED tPBM commercial device

Methods

Protocol: Three tPBM protocol types (Table) were tested during resting state EEG recording (N=8).

tPBM: 256, 1040 nm LED tPBM device by Neuronic Online

EEG: Single channel in-ear EEG with no electrical interference was used for real time global measurements

24-channelmeshcapEEGwasusedforintermittent regional and network measurements

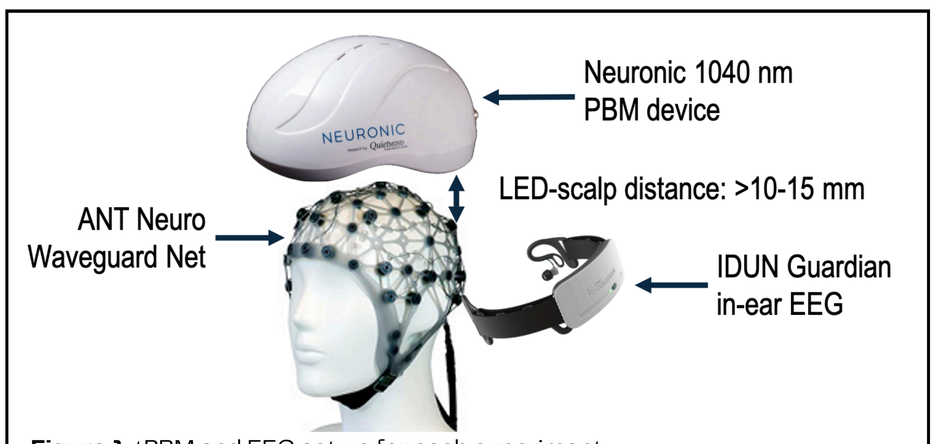

Figure 1. tPBM and EEG set up for each experiment.

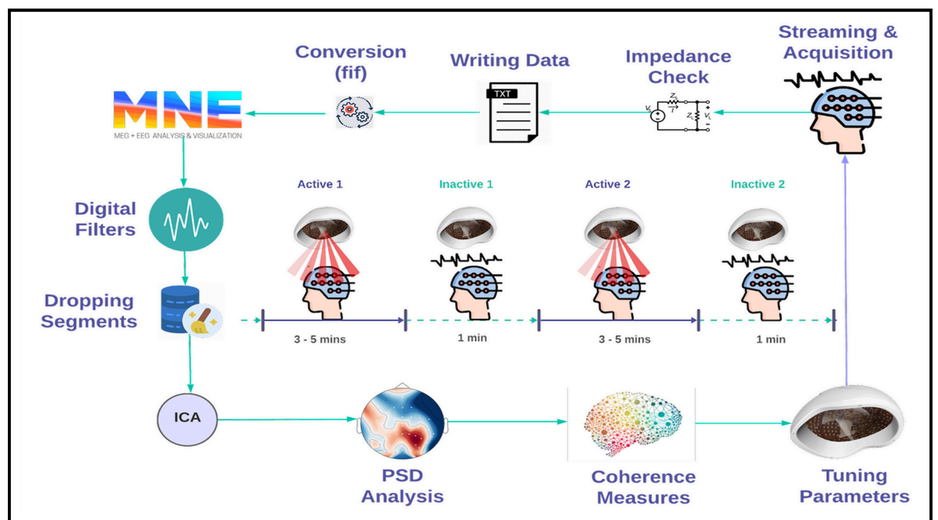

Figure 2. Analysis pipeline for 24-channel EEG. Includes future objective of closed loop tPBM parameter tuning.

Table 1. tPBM Protocols and Candidate EEG Metrics

Protocols Parameters	Pulsed	Continuous	Proxy Continuous
Duty Cycle (25, 50, 75, 100 %)	50	100	50
Duration (1 - 30 minutes)	10	10	10
Pulse Rate (1-9999 Hz)	10	NA	1000
EEG Candidate Metric (Frequency domain)	▲ Global α	▼$\delta - \theta$	▼$\delta - \theta$
Energy Density per Cycle (J/cm² for 1040 nm)	0.524	1.047	0.524

Preliminary Results

Hypothesis: Candidate EEG metrics expected to change within three minutes of stimulation, based on clinical EEG observations.

Finding: No consistent and predictable change in alpha power during 10Hz protocol or decrease in theta power during continuous protocol.

Spatial patterns of PSD suggest symmetrical fluctuations in power by frequency bands.

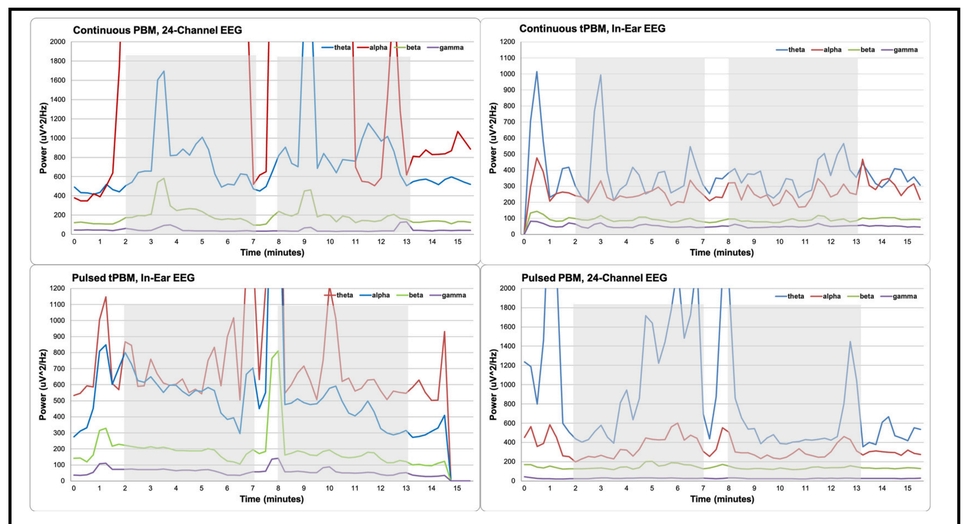

Figure 3. Individual global absolute PSD results from 5-minute stimulation periods (grey) from unique sessions. Pulse frequency is 10Hz. Proxy continuous data not shown.

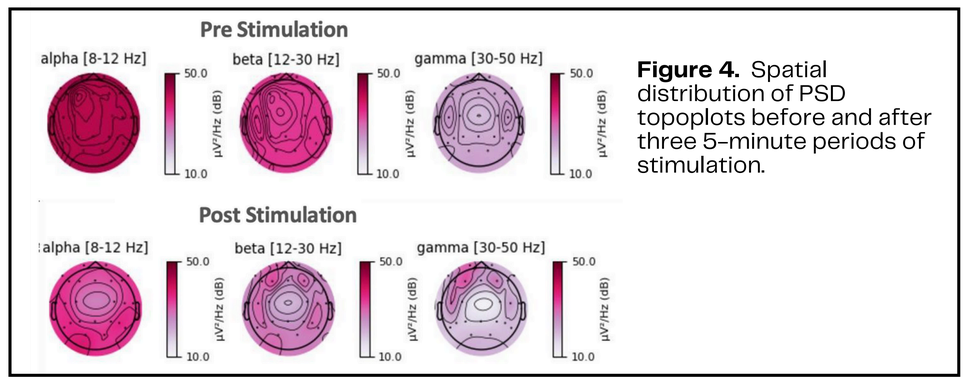

Figure 4. Spatial distribution of PSD topoplots before and after three 5-minute periods of stimulation.

Future Directions

Alternative Metrics: Interhemispheric connectivity may be modulated by tPBM and will be analyzed in 24-channel datasets. Systemic and autonomic effects of tPBM will be accounted for with concurrent blood pressure and pulse measurements in future experiments.

Alternative Experiments: In a healthy population, tPBM effects may not be detectable at rest. Psychometric tests with known neural correlates that are sensitive to participant state will be conducted. tPBM may effect both cogntive scores and EEG metrics.

Table 2. Alternative Testing Paradigms

Biometric	Expected Change	Test	Expected Change
Blood Pressure	▼	**Working Memory**	Longer digit span ▼ frontal $\theta:\gamma$
HRV	▲	**Processing Speed**	Faster reaction time ▼ frontal $\theta:\beta$

Broader Vision: Design a closed-loop tPBM system responsive to brain activity metrics

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