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Comparative Analysis of the NeuroExo™, the Stentrode™, and the N1™ BCI devices

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Introduction: Technology has revolutionized how we interact with others and view the world, with advancements in neural engineering enabling communication for users previously unable to do so. This technology, known as brain computer interfaces (BCI) translate brain activity into commands for virtual or physical machines to restore or rehabilitate motor, sensory or speech functions [1]. However, the recent convergence of BCIs and IoT can enable direct brain communication with appliances, vehicles, and even people [2]. This fosters advancements in communication for a diverse range of individuals, enhancing connectivity and interaction for all. Three BCI systems that stand out in creating devices that converge BCI and IoT are the NeuroExo from the BRAIN Center at University of Houston, the Stentrode from Synchron™, and the N1 implant from Neuralink™. This study aims to compare these three BCI devices in terms of their usability, device specifications, and trade-offs.

Material, Methods and Results: Data were sourced from peer-reviewed studies, patents, and company documentation. The product and engineering specifications of the BCIs were assessed based on the following categories: invasiveness, signal modality and processing, machine learning and tasks performed. NeuroExo is entirely non-invasive, using an external electroencephalography (EEG) headset with self-positioning dry comb electrodes, while Stentrode requires minimally invasive surgery as it is placed into the superior sagittal sinus via the jugular vein, and N1 involves major intracranial surgery to place an implant directly on the motor cortex. Resolution also varies with invasiveness: NeuroExo has 8 channels with a sampling frequency (SF) of 500 Hz, Stentrode features 16 channels and has a SF of 2 kHz, and N1 offers 1,024 channels at a SF of 19.3 kHz. Signal modalities reflect similar trends. NeuroExo measures EEG and electrooculography (EOG) up to 131 Hz, suitable for movement related cortical potentials. Stentrode detects vascular electrocorticography (vECOG) up to 250 Hz, while N1 measures LFP and action potentials (AP) for the most granular neural data up to 3-27 kHz. All three BCI devices have analog signal conditioning (e.g., Bandpass filtering), but only the NeuroExo includes digital adaptive noise canceling necessary for artifact identification and removal. Classification algorithms include support vector machine (SVM) and linear discriminant analysis for NeuroExo and SVM for Stentrode, with N1 employing a custom spike detection system. IoT compatibility highlights distinctions, with NeuroExo seamlessly integrating BT and Wi-Fi. Stentrode relies on RF, while N1 claims BT support. The three BCI systems differ in the scope of tasks performed. Stentrode trials include communication tasks such as unsupervised typing at home, while NeuroExo focuses primarily on upper-limb stroke neurorehabilitation at both the clinic and at home. As per company social media posts, N1 has reported gaming applications, such as chess. Standardized and transparent testing protocols, as well as user, clinical and engineering outcome metrics are needed to allow quantitative comparison of these BCI systems.

Conclusion: The devices differ in invasiveness: NeuroExo is non-surgical, while Stentrode and N1 require surgical implantation. Stentrode and N1 have received an IDE from the FDA, while there is an FDA approved BCI predicate to NeuroExo. Despite differences, all three systems enable IoT integration, advancing connectivity and user interaction. This study underscores the importance of balancing risk, functionality, and user preferences to guide device selection in an increasingly IoT-connected world.

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