Low-Latency EEG Marker Integration in Serious Games for Neurocognitive Assessment

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2025

"The concern for man and his destiny must always be the primary interest of any technical effort. Never forget this between your diagrams and equations"

Albert Einstein

"Believe you can, and you are halfway there."

Theodore Roosevelt

Declaración

Me permito afirmar que he realizado esta tesis de manera autónoma y con la única ayuda de los medios permitidos. Todos los pasajes que se han tomado de manera textual o figurativa de textos publicados y no publicados, los he reconocido en el presente trabajo. Ninguna parte del presente trabajo se ha empleado en ningún otro tipo de tesis.

Manizales, 2025

Julian Andres Salazar Parias

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2025

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1 Preliminaries

1.1 Motivation

Brain–Computer Interfaces (BCIs) have emerged as a powerful class of technologies that enable direct communication between the brain and external devices. These systems are increasingly being applied in neurorehabilitation, education, and clinical diagnosis due to their ability to monitor and interpret neural activity in real time. BCIs have the potential to revolutionize the way cognitive states are assessed and modulated by offering closed-loop interaction mechanisms that adapt to the user's brain dynamics [**?**, **?**]. Central to this capability is the choice of neuroimaging modality, which must meet strict criteria in temporal resolution, portability, and cost-effectiveness—especially in applications involving children or naturalistic settings.

Several neuroimaging techniques have been explored for use in Brain–Computer Interface (BCI) systems, each with distinct advantages and limitations. Functional Magnetic Resonance Imaging (fMRI) offers high spatial resolution and whole-brain coverage, but its cost, immobility, and dependence on specialized facilities make it impractical for real-time interaction or integration with everyday environments [**?**]. Magnetoencephalography (MEG) provides excellent spatiotemporal resolution but is similarly constrained by high operational costs and the need for magnetically shielded rooms [**?**]. Functional Near-Infrared Spectroscopy (fNIRS), a more portable option, measures cortical hemodynamic responses with moderate spatial resolution and tolerance to movement [**?**]. However, its low temporal resolution limits its ability to capture fast-changing neural dynamics, such as those required for attentional monitoring or neurofeedback.

Electroencephalography (EEG), by contrast, emerges as the most suitable modality for BCI applications that demand real-time responsiveness, portability, and affordability. EEG records the brain's electrical activity through non-invasive scalp electrodes, offering millisecond-level temporal resolution ideal for tracking rapid cognitive events like attention shifts or inhibitory control. While EEG's spatial resolution is lower compared to fMRI or MEG, advances in signal processing—such as QEEG, functional connectivity analysis, and source localization—have greatly enhanced its ability to extract meaningful neurophysiological markers [**?**, **?**, **?**].

Moreover, EEG's lightweight hardware, low infrastructure requirements, and compatibility with embedded systems make it an ideal foundation for interactive, portable, and scalable BCI solutions.

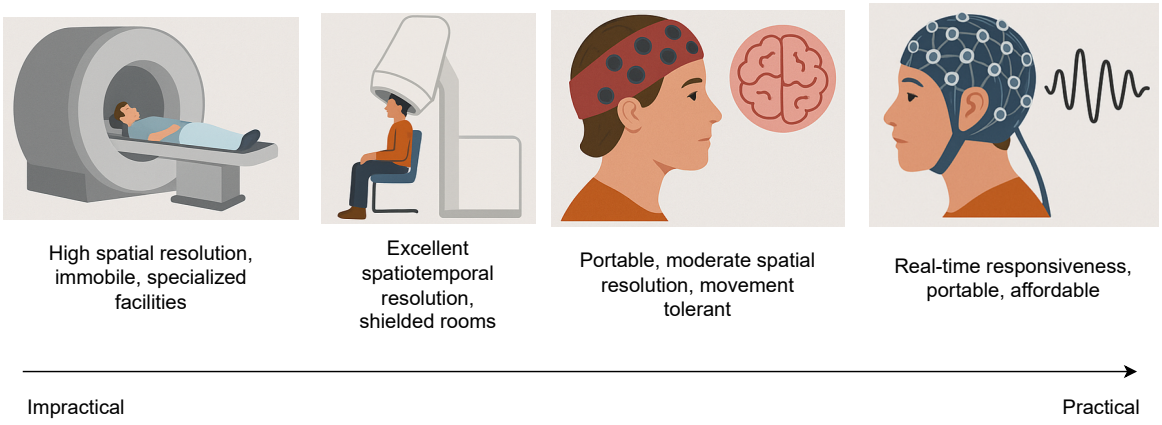

Figure 1-1: Comparison of neuroimaging modalities by spatial resolution, temporal resolution, and cost. EEG stands out for its affordability, portability, and millisecond-level responsiveness.

One of the most compelling clinical applications of EEG-based BCIs is in the assessment and intervention of neurodevelopmental disorders such as Attention Deficit Hyperactivity Disorder (ADHD). ADHD affects approximately 10 % of children in Colombia [**?**, **?**] and is characterized by persistent symptoms of inattention, hyperactivity, and impulsivity that interfere with academic performance, social relationships, and emotional regulation. Conventional diagnostic practices rely heavily on behavioral questionnaires and clinical observation, which, while informative, are inherently subjective and susceptible to bias [**?**]. In this context, EEG offers a valuable alternative by enabling the objective measurement of neural correlates linked to attention and impulse control. Well-established EEG biomarkers such as elevated theta/beta ratios and altered event-related potentials (e.g., P300) have been extensively validated in the ADHD literature, making EEG a scientifically robust and clinically relevant tool for real-time cognitive monitoring and neurofeedback interventions.

Serious games are digital environments designed not solely for entertainment, but to fulfill educational, therapeutic, or cognitive objectives. In the context of neurodevelopmental disorders such as ADHD, they have become increasingly relevant as tools for both cognitive assessment and intervention [**?**]. Their engaging and adaptive nature allows them to target specific executive functions—like attention, inhibition, and working memory—while maintaining high user motivation, particularly among children [**?**]. These features make serious games particularly compatible with EEG-based BCIs for interactive cognitive modulation.

Serious games designed for ADHD not only provide engaging environments for cognitive stimulation, but also serve as structured frameworks for assessing and training specific executive functions. Two principal paradigms guide the design of these games. The first is the task-based paradigm, which integrates classical neuropsychological tasks—such as the

Go/No-Go, n-back, or Stroop test—into interactive game mechanics. This allows for the precise measurement of behavioral responses tied to well-established cognitive models [?]. The second is the neurofeedback paradigm, in which the game dynamically responds to real-time EEG signals, offering auditory or visual feedback based on the user's brain state. This paradigm supports operant conditioning mechanisms, encouraging users to self-regulate neural activity linked to attentional control and inhibition [?].

These paradigms are often aligned with four core cognitive models critical to ADHD pathology: attention, working memory, inhibition, and planning. Games targeting the attentional model aim to improve sustained and selective attention, often requiring players to maintain focus amid distractions or shifting stimuli [?]. Working memory is typically trained through tasks that require the temporary storage and manipulation of information, such as remembering sequences or updating mental representations. The inhibition model involves suppressing prepotent responses or resisting distractions—commonly implemented through fast-paced decision-making challenges or impulse control mechanics [?, ?]. Finally, the planning model emphasizes goal-directed behavior, encouraging users to sequence actions, solve multi-step problems, or anticipate future outcomes [?]. By aligning game mechanics with these cognitive models, serious games become powerful tools not only for engagement but for targeted neurocognitive intervention, particularly when combined with EEG-based BCIs that provide objective feedback on brain performance in real time.

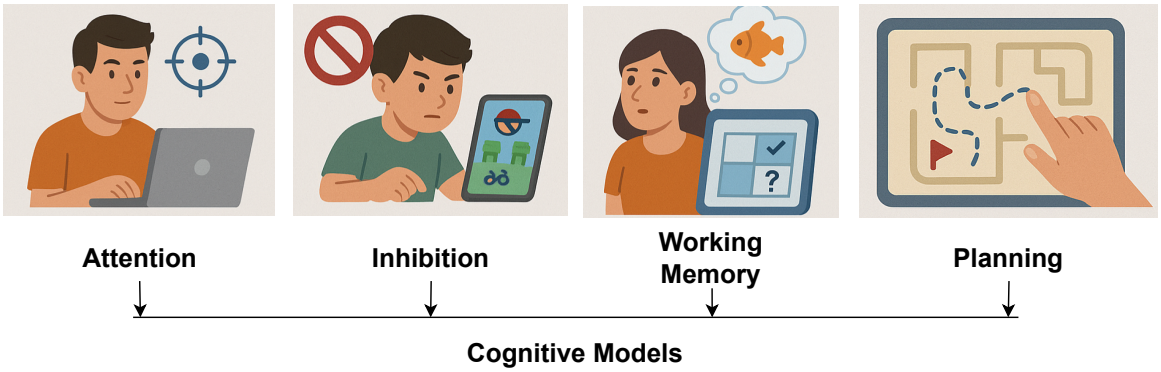

Figure 1-2: Core cognitive models targeted by serious games in ADHD interventions: attention, working memory, inhibition, and planning. Each model maps to a specific set of game dynamics and EEG markers.

Serious games integrated with BCI technology have demonstrated therapeutic benefits by reinforcing executive function, improving behavioral outcomes, and reducing symptom severity through active attention training and neurofeedback mechanisms [?]. Active BCIs, in which users intentionally modulate their focus to influence the outcome of the game, have been shown to strengthen cognitive control and promote long-term neuroplastic changes relevant to ADHD pathology [?]. These platforms also enable adaptive feedback, allowing interventions to dynamically adjust to each child's neurocognitive profile.

However, the effectiveness of such systems depends on precise temporal synchronization

between game-generated stimuli and EEG signals. Detecting event-related potentials (such as the P300 wave) or dynamic oscillations in the theta and beta frequency bands during attentional tasks requires sub-millisecond timing accuracy [**?**, **?**]. Without rigorous synchronization—typically achieved via TTL triggers or low-latency USB/Wi-Fi communication—EEG signal interpretation is susceptible to noise, jitter, and event misclassification [**?**]. This challenge is particularly critical in real-time therapeutic environments where accurate feedback is essential.

Recent developments in portable EEG hardware have expanded the applicability of BCIs for ADHD beyond clinical settings, enabling real-time monitoring and feedback in homes, classrooms, and therapeutic environments. Low-cost, wireless EEG headsets—equipped with dry electrodes and embedded microcontrollers—have been successfully integrated into neurofeedback systems and serious games designed for children [**?**]. These platforms allow for real-time signal acquisition and onboard processing, supporting closed-loop interventions without reliance on external computers. Thanks to ARM-based processors and system-on-chip (SoC) designs, it is now possible to run lightweight machine learning models directly on the device for real-time EEG classification [**?**]. Moreover, custom head-mounted EEG systems have shown reliable tracking of the theta/beta ratio, a key biomarker for ADHD, during interactive tasks [**?**].

Altogether, these technological advances offer a promising foundation for rethinking ADHD diagnosis and intervention—especially in child populations. Nevertheless, critical technical challenges remain, particularly the synchronization of cognitive stimuli with neurophysiological responses in embedded systems. This challenge motivates the present research, which aims to design and implement a portable EEG acquisition and analysis system with precise synchronization to game events, enabling objective, real-time support for cognitive stimulation and diagnostic processes in children with ADHD.

1.2 Problem statement

The design and implementation of serious games synchronized with neurophysiological signals such as electroencephalography (EEG) presents a critical challenge, especially when targeting cognitive stimulation and diagnostic support in pediatric populations with Attention Deficit Hyperactivity Disorder (ADHD). The scientific validity of such applications is fundamentally dependent on the precise temporal synchronization of at least two disparate data streams: the high-temporal-resolution physiological data from the EEG system and the context-dependent event data generated by the serious game. A core technical obstacle lies in achieving this precise synchronization, a requirement that is essential for both the accuracy of event-related potential (ERP) measurements and the effectiveness of real-time interventions.1 This thesis addresses two primary facets of this challenge: the temporal inaccuracies introduced by system-level operations and the physical limitations of the hardware itself.

1.2.1 Unpredictable Latency and Jitter Between Game Events and EEG Recordings

The primary technical issue in synchronizing EEG data with serious game events is the presence of unpredictable latency and jitter.2 Latency is the delay between an event's physical occurrence (e.g., a stimulus appearing on screen) and its corresponding timestamp being recorded in the data stream. A more pernicious issue is jitter, defined as the statistical variability in that latency over time.4 While a constant latency might be correctable in post-processing, jitter introduces random, unpredictable timing errors that cannot be easily removed after data acquisition. This issue is caused by several interrelated factors: buffering delays in data pipelines, the non-deterministic scheduling of non-real-time operating systems, variability in communication protocols (such as USB, Bluetooth, or the Lab Streaming Layer), and asynchronous execution within game engines like Unity.5 These conditions lead to a lack of temporal precision, where the timestamp of an in-game event does not accurately align with the corresponding entry in the EEG data stream. This misalignment significantly compromises the quality of neurophysiological analysis. ERP components such as the P300 and N200, which are commonly used to evaluate attentional processes in ADHD, depend on millisecond-level synchronization between stimulus onset and neural response.7 When event markers are not precisely aligned due to jitter, the resulting ERP waveform becomes temporally "smeared,çausing a reduction in both amplitude and interpretability, which degrades the signal-to-noise ratio and threatens diagnostic reliability.2 This is particularly critical in pediatric populations where subtle attentional deficits are being assessed. Furthermore, in real-time systems like neurofeedback applications, where immediate feedback is essential for operant conditioning, even minor delays can disrupt the feedback loop. If the user receives auditory or visual feedback that no longer corresponds precisely to their brain state, the therapeutic effectiveness is reduced, potentially leading to user disengagement or ineffective

training outcomes.2 The temporal precision required is demanding; some brain-computer interface (BCI) paradigms require accuracy within ±2 milliseconds, yet jitter introduced by a game's graphical rendering at 50 frames per second can be as high as 20 milliseconds. Recent studies have quantified these challenges. For example, Larsen et al. (2024) found that even in systems optimized with Unity and LSL, event marker delays averaged 36 milliseconds with a jitter of 5 to 6 milliseconds—well above the acceptable margin for many ERP analyses.9 Additionally, Brain Products (2024) reports that embedded platforms lacking efficient buffering and timestamping can exhibit latencies up to 100 milliseconds, particularly under high computational load.5 These delays, caused by a lack of dedicated real-time scheduling and protocol optimization, result in a substantial loss of synchronization fidelity, ultimately undermining both research validity and clinical utility.

1.2.2 Resource and power constraints in embedded EEG platforms

The second major issue stems from the computational and energy limitations of embedded and wearable EEG systems. Designed to be mobile and unobtrusive, these systems often operate on limited battery power, constrained CPU cycles, and reduced memory.11 These constraints are exacerbated when the system must simultaneously support real-time data acquisition, multichannel EEG streaming, and high-frequency event marker registration. Conventional EEG setups that rely on centralized data processing can also lead to high energy consumption and increased data transmission latency.12 These limitations make it difficult to implement low-latency communication and high-resolution timestamping. Wireless data transmission, in particular, is very power-intensive.13 Protocols such as Bluetooth and Wi-Fi—commonly used in portable EEG systems—can introduce packet retransmissions, buffering delays, and inconsistent delivery times that worsen synchronization accuracy.5 The consequences are significant. System designers are forced to lower EEG sampling rates, simplify marker handling, or accept increased delays—all of which reduce the reliability of the collected data and the interactivity of the game.14 For example, a review of wearable EEG systems found that wireless devices consistently showed worse timing stability and synchronization performance compared to wired configurations, especially when embedded resources were under heavy computational load. Brain Products (2024) corroborates these findings, warning that system performance degrades as channel count and sampling rate increase—conditions commonly required in clinical-grade EEG systems.5 This creates a fundamental trade-off: increasing signal fidelity and temporal resolution compromises system portability, while optimizing for mobility sacrifices diagnostic precision. Therefore, a critical gap exists in establishing a robust methodology to reliably synchronize multimodal data streams from EEG systems and dynamic serious games with quantifiable, millisecond-level precision, while also operating within the power and resource constraints of embedded platforms. This thesis addresses the problem of ensuring the temporal integrity of these data streams to enable scientifically valid analysis of neuro-cognitive processes during gameplay.

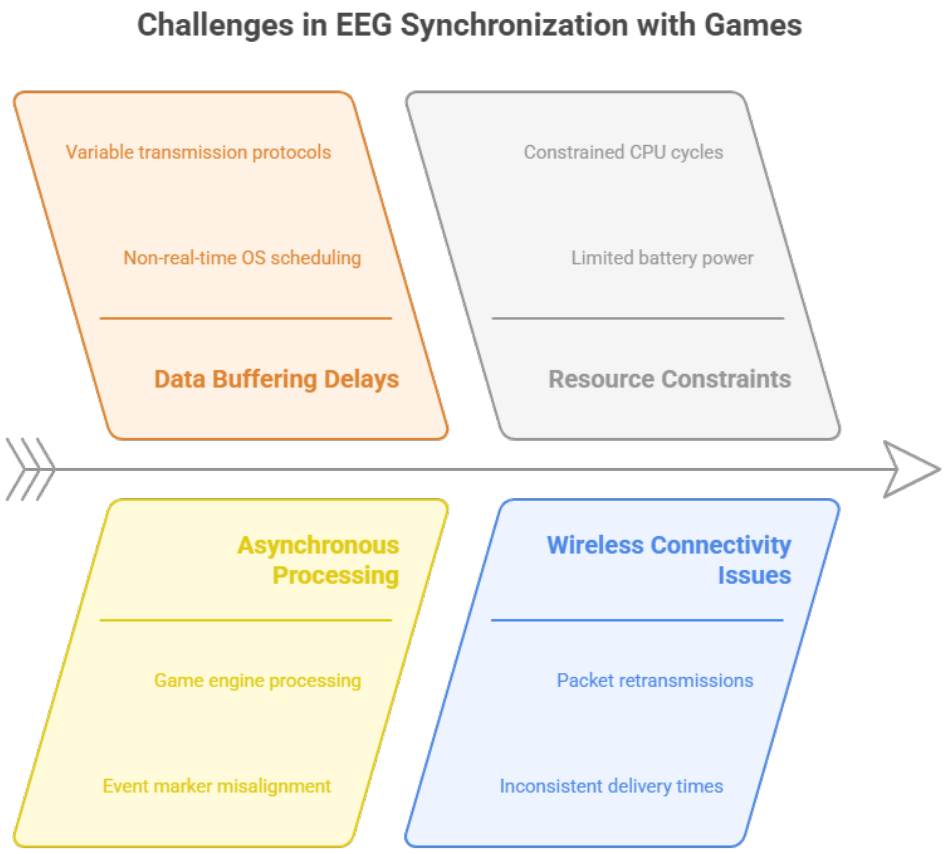
Challenges in EEG Synchronization with Games
Variable transmission protocols
Non-real-time OS scheduling
Data Buffering Delays
Constrained CPU cycles
Limited battery power
Resource Constraints
Asynchronous Processing
Game engine processing
Event marker misalignment
Wireless Connectivity Issues
Packet retransmissions
Inconsistent delivery times

Figure 1-3

1.3 Pregunta de investigación

How can a low-latency and low-jitter data synchronization framework be developed and validated to ensure the temporal integrity of multimodal data from embedded EEG systems and dynamic serious game events, while respecting the inherent resource and power constraints of such platforms?

1.4 Aims

1.4.1 Objetivo General

Diseñar e implementar una arquitectura de adquisición de señales EEG optimizada para aplicaciones en entornos educativos y clínicos, enfocada en la reducción de latencias y la sincronización precisa de eventos, para mejorar la evaluación objetiva de patrones cognitivos y emocionales en niños con TDAH.

1.4.2 Objetivos Específicos

1. Analizar las limitaciones técnicas de los sistemas actuales de adquisición de EEG, incluyendo las latencias de transmisión y la baja densidad de canales.
2. Desarrollar algoritmos de baja latencia y estrategias de sincronización temporal para garantizar la alineación precisa entre estímulos de juegos serios y respuestas EEG.
3. Evaluar la arquitectura propuesta en entornos clínicos y educativos, verificando su eficacia en el diagnóstico y tratamiento del TDAH.

1.5 Estado del arte

In recent years, numerous wireless systems for EEG data acquisition have been developed, with two main approaches standing out: conventional remote monitoring systems and portable smart systems. The former simply digitize the EEG signals and transmit them to a remote unit for processing, usually in a deferred manner [**?**]. On the other hand, portable systems preprocess the signals on a local device, such as a microcontroller (MCU), and wirelessly transmit the data using low-power consumption protocols. **1-1** This latter approach is crucial for real-time applications, where low latency is essential.

Marker synchronization in portable EEG acquisition systems [**?**], particularly in applications combined with serious games [**?**], faces several technical and operational challenges. One of the main issues lies in latency in data transmission protocols. In portable EEG systems, precise synchronization between brain events and interactions in the game is crucial [**?**], but inherent limitations of portable acquisition systems, such as latencies in data transfer protocols, can cause temporal mismatches. These latencies primarily stem from bandwidth constraints in wireless transmission and the need to process large volumes of data in real-time [**?**].

The type of electrode [**?**] and the number of channels [**?**] are determining factors in the quality of the data acquired in portable systems. Although dry electrodes offer greater portability, they tend to generate lower-quality signals due to reduced conductivity, which can complicate precise synchronization with other devices, such as serious games. On the other hand, the use of systems with **low channel density (e.g., 8-16 channels)** [**?**] is a common strategy in these portable systems to minimize size and improve portability. However, low channel density can affect the spatial resolution of EEG data, limiting the ability to perform accurate analysis of brain patterns. This challenge is reflected in the need to optimize sampling [**?**] and data transfer protocols [**?**] to ensure that captured signals are transmitted efficiently without significant information loss

The sampling rate is another critical factor, as it directly affects the temporal resolution of EEG signals. The combination of low channel density and insufficient sampling rate can make it difficult to capture fast brain events, such as attention shifts, which are essential in applications like serious games. Furthermore, Signal Front-End Amplifiers (AFE) [**?**] play a key role in signal quality. While low-cost AFEs may be suitable for portable systems, they tend to have limitations in processing capacity, which impacts data synchronization by generating noise and distortions in the EEG signals, especially when connected to mobile devices with lower processing power.

Battery life [**?**] is a significant constraint for portable systems that require long monitoring sessions. EEG systems that operate for several hours often need to optimize their energy consumption, which may involve reducing the sampling rate or channel density, once again impacting data quality and real-time synchronization.

Table 1-1: Dispositivos de adquisición utilizados para BCI. La tabla ofrece una descripción general de los diferentes dispositivos de hardware, sus especificaciones y protocolos de comunicación.

Hardware BCI	**Empresa**	**Tipo de Electrodo**	**Canales**	**Frecuencia de Muestreo**	**AFE**	**Protocolo y Transferencia de Datos**	**Duración de la Batería**
Cyton + Daisy [**?**]	OpenBCI	Flexible / Húmedo / Seco	16	250 Hz- - 16 kHz	ADS1299	RF / BLE / Wi-Fi	8 h
actiCAP [**?**]	Brain Products GmbH	Flexible / Húmedo / Seco	16	256 Hz- - 16 kHz	-	USB	16 h
EPOC X [**?**]	Emotiv	Rígido / Húmedo	14	128 Hz	-	BLE / Bluetooth	6–12 h
Diadem [**?**]	Bitbrain	Rígido / Seco	12	256 Hz	-	Bluetooth	8 h
g.Nautilus [**?**]	g.tec	Flexible	8 / 16 / 32	250 Hz	ADS1299	Propietario	10 h
Plataforma para EEG ambulatorio [**?**]	-	Activo / Seco	32	250 Hz- - 1 kHz	ADS1299	Wi-Fi 802.11 b/g/n	26 h
Sistema para neurofeedback [**?**]	-	Pasivo / Seco	40	250 Hz	ADS1298	RF	-
BEATS [**?**]	-	Flexible / Húmedo	32	4 kHz	ADS1299	Wi-Fi	24 h (cableado)

In the field of brain-computer interfaces (BCIs), several devices have been developed, each with unique features tailored to specific use cases such as clinical research, neurofeedback, or consumer applications. The Cyton + Daisy system by OpenBCI [**?**] supports up to 16 channels and offers a wide sampling rate range of 250 Hz to 16 kHz, making it suitable for high-resolution EEG acquisition. The device uses flexible, wet, or dry electrodes and incorporates the ADS1299 AFE for high-quality signal conversion. It supports data transfer via RF, Bluetooth Low Energy (BLE), and Wi-Fi, allowing for versatile connectivity. With a battery life of 8 hours, this system is highly adaptable, suitable for both research and practical applications in various environments. Another system, actiCAP [**?**] by Brain Products GmbH, features flexible, wet, or dry electrodes and is capable of recording up to 16 channels with a

sampling rate range from 256 Hz to 16 kHz. The actiCAP does not use a dedicated AFE and instead relies on a USB protocol for data transfer. The device provides a robust 16-hour battery life, making it an ideal choice for long-duration experiments and clinical settings that require stable signal acquisition over extended periods. The EPOC X [**?**] by Emotiv is a more compact and consumer-oriented BCI device that uses rigid, wet electrodes and supports 14 channels with a sampling rate of 128 Hz. This device employs Bluetooth Low Energy (BLE) for wireless data transfer, and its battery life ranges from 6 to 12 hours, depending on usage. While its lower sampling rate may limit its use for high-resolution research, the EPOC X remains a popular choice for applications in neurofeedback, cognitive training, and general user interaction. The Diadem [**?**] system by Bitbrain uses rigid, dry electrodes and supports 12 channels with a sampling rate of 256 Hz. It operates via Bluetooth for data transmission and has a battery life of 8 hours, providing a balance between portability and signal quality. The g.Nautilus [**?**] system by g.tec offers great flexibility, supporting configurations with 8, 16, or 32 channels. It operates at a sampling rate of 250 Hz and uses the ADS1299 AFE for high-performance signal acquisition. The system is known for its proprietary data transmission protocol, ensuring reliable connectivity, and its battery lasts up to 10 hours, making it suitable for long-term monitoring and research studies. The BCI system used by [**?**] employs active, dry electrodes and supports up to 32 channels with a sampling rate range of 250 Hz to 1 kHz. It also incorporates the ADS1299 AFE for analog-to-digital conversion, ensuring high fidelity in signal capture. Data is transferred via Wi-Fi 802.11 b/g/n, enabling flexible and high-speed communication with external devices. The system boasts an impressive 26-hour battery life, making it an excellent option for extended usage in field studies or clinical applications. The BCI system described by [**?**] uses passive, dry electrodes and supports up to 40 channels with a sampling rate of 250 Hz. It incorporates the ADS1298 AFE for high-quality data acquisition and utilizes RF (Radio Frequency) for data transfer. While battery life details are not specified, this device is likely designed for portable, research-focused applications where wireless data transfer is essential for real-time monitoring. Finally, the [**?**] system features 32 flexible, wet electrodes and uses the ADS1299 AFE for high-precision EEG signal acquisition at a sampling rate of 4 kHz. Data is transmitted wirelessly via Wi-Fi, allowing for real-time data monitoring and analysis. The system's battery life is 24 hours when wired, providing extended operation for intensive studies or clinical assessments that require continuous monitoring.

Each of these devices represents a different approach to EEG signal acquisition, offering varying numbers of channels, electrode types, sampling rates, and battery life. While some are optimized for research and clinical use with high sampling rates and extended battery life, others are more suited to consumer applications with lower sampling rates and shorter operational times. The choice of device depends largely on the specific needs of the user, whether for research, clinical monitoring, or personal use in neurofeedback and cognitive training applications.

2 Theoretical Framework

2.1 Neurophysiology & ERPs

Explanation of Event-Related Potentials (P300, N200) and why millisecond-level precision is required to detect them.

2.2 Signal Acquisition Hardware

2.2.1 Delta-Sigma ADCs

Theory behind the TI ADS1299 (24-bit resolution, simultaneous sampling).

2.2.2 Heterogeneous Embedded Systems

The role of the MCU (Real-time determinism) vs. the MPU (Linux/Compute Module for data throughput).

2.3 Digital Synchronization Protocols

Comparison of synchronization methods: Optical (Photodiodes), Network (LSL), and Serial/USB interfaces. USB latency characteristics (polling rates, CDC class overhead).

3 Hardware Architecture (The MONEEE System)

3.1 System Overview & Block Diagram

High-level data flow: Electrodes → ADS1299 → TM4C1294 → RPi CM4.

3.2 Analog Front-End (AFE)

Configuration of the ADS1299. Bias drive implementation (Driven Right Leg) for noise rejection. Power supply isolation (Battery management integration).

3.3 The Digital Core (The Split-Architecture)

3.3.1 Real-Time Unit (TI TM4C1294)

Chosen for its hardware floating-point unit and deterministic interrupt handling. It acts as the SPI master for the ADS1299.

3.3.2 Compute Unit (Raspberry Pi CM4)

Handling high-bandwidth data storage and potential Wi-Fi transmission.

3.3.3 Inter-Processor Communication

How the TM4C sends data to the RPi (e.g., via high-speed SPI or UART).

3.4 The Event Interface (USB-C)

Hardware implementation of the USB Type-C port. Signal conditioning: Ensuring the tablet's USB power/data lines do not introduce noise into the EEG ground.

4 Firmware and Synchronization Strategy

4.1 TM4C1294 Firmware Design

4.1.1 Interrupt Service Routines (ISR)

Using the ADS1299 DRDY (Data Ready) pin to trigger data retrieval.

4.1.2 The "Timestamping.^{En}gine

This is the core contribution. The Tablet sends a Hex Code (e.g., 0x0A for "Target Appears"). The TM4C receives this via USB/Serial. The firmware must instantly inject this code into the current EEG sample packet before sending it to the RPi.

4.2 Serious Game Integration

Description of the library used on the Tablet side to send Hex codes. Protocol definition (Start byte, Event Code, End byte).

4.3 Raspberry Pi CM4 Software

Linux kernel configuration for real-time performance (optional: PREEMPT_RT). Data formatting (e.g., converting raw bytes to EDF+ or XDF formats).

5 Validation and Results

5.1 Signal Quality Verification

Noise floor analysis (Input-shorted test). Frequency response analysis.

5.2 Synchronization Latency Analysis (Crucial)

5.2.1 The Round-Trip"Test

A test setup where the tablet flashes the screen AND sends the Hex code. A photodiode measures the screen, and the MONEEE records the Hex code. The time difference is the System Latency.

5.2.2 Jitter Measurement

Quantifying the variability of the USB transmission.

5.3 Proof of Concept

A pilot recording of a P300 response using the Serious Game on a healthy subject.

6 Conclusion and Future Work