



CipherPal: A Privacy-Preserving Smart Fidget Device for Mindful Data Collection and Storage

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Abstract

This demonstration paper presents CipherPal, a next-generation prototype that integrates advanced mood-related sensing, on-device encryption, and decentralized storage to deliver a secure and ergonomic interface for personal digital interactions. Our research builds upon previous explorations to create an interactive smart fidget device that makes the experience of secure biometric and interaction data collection natural and engaging. This paper discusses how we can utilize blockchain technology alongside interaction design to foster a more mindful and sustainable approach to personal data management. The device features dual heartbeat sensors integrated into natural interaction points, and LED feedback for different device states. Users can securely store their interactions using IPFS storage and blockchain technology through its companion application, maintaining complete control over their data. CipherPal investigates the delicate balance that must be kept for sustainability between data sharing and digital privacy.

CCS Concepts

• **Security and privacy** → Human and societal aspects of security and privacy; Usability in security and privacy; • **Human-centered computing** → Interaction Design.

Keywords

Web3, wearable device, blockchain, distributed storage, data privacy

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1 Introduction

We face a fundamental conflict in healthcare data management: how can we leverage the potential of data-driven insights while maintaining our right to govern personal information? CipherPal addresses this challenge by reimagining how to mindfully collect and securely manage personal health data through natural, tactile interactions.



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Our previous study [3] introduced a smart fidget toy utilizing blockchain technology to secure mood- and health-related data through decentralized storage. Blockchain has been recognized as a secure approach to managing sensitive health data using cryptographic techniques and smart contracts [1]. Wearable technology based on blockchain effectively manages health data while protecting patient privacy [5].

The current CipherPal iteration introduces hardware and software improvements. By emphasizing active user awareness over passive tracking, it helps users understand their data's value by engaging with privacy settings rather than passive background safeguarding. Research suggests privacy tools should integrate motivational design principles balancing risk perception with user control [6].

To improve reliability, we've created a custom PCB with dual heartbeat sensors that enhance data collection without compromising ergonomics. CipherPal improves data sustainability through on-device encryption, InterPlanetary File System (IPFS), a peer-to-peer protocol for distributed data storage and sharing [7], and blockchain technologies, making data storage efficient. Unlike traditional centralized storage systems, this architecture ensures user ownership while maintaining high performance and reliability at lower costs compared to on-chain storage systems [2, 4].

The accompanying application streamlines the process of data sharing and oversight by providing a simple interface for data visualization and administration.

This paper examines how incorporating well-considered digital and physical components might result in more sustainable methods for managing and collecting personal health data. With its innovative physical design, improved user engagement, and secure data storage, CipherPal presents a promising future for personal health management.

2 CipherPal Device

2.1 Physical Design

The device architecture comprises three primary functional components (Figure 1):

- **Base Module with Integrated Rotary Mechanism:** The foundational component incorporates a rotary encoder that allows users to rotate the entire device body.
- **Main Circuit Board:** A custom double-sided PCB contains the device's core electronics, including the microcontroller with flash memory, power management system with a rechargeable LiPo battery, and sensors.

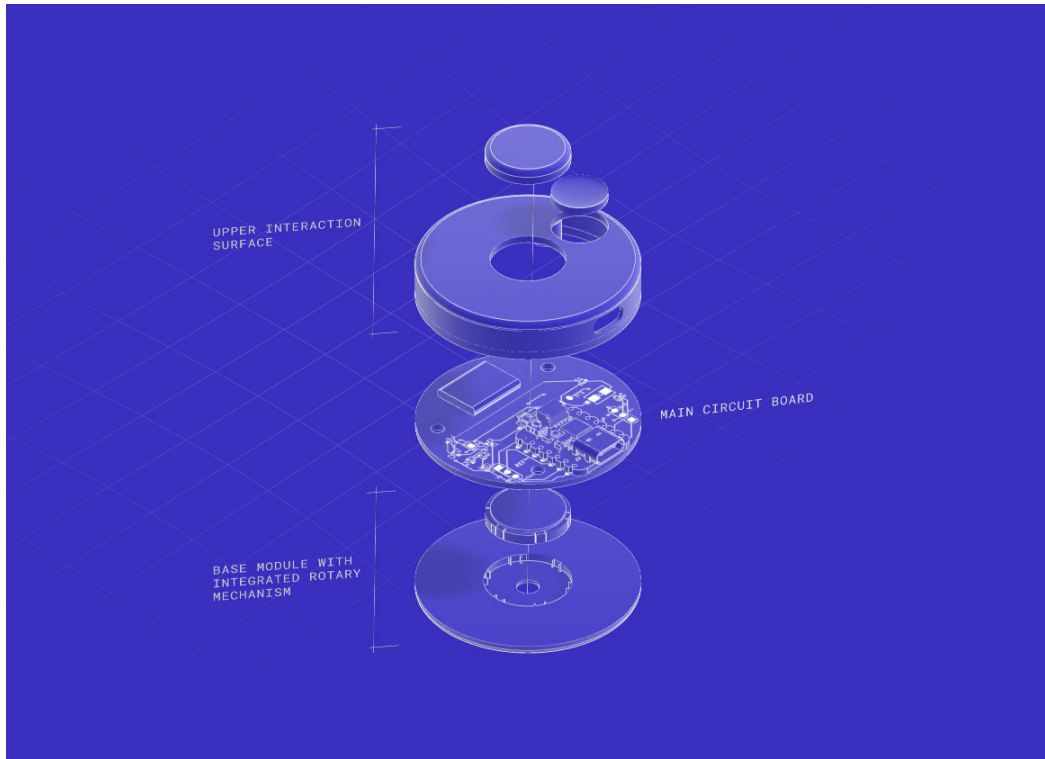


Figure 1: Exploded Isometric 3D Model of the Device.

- **Upper Interaction Surface:** The top surface features a tactile button and rotating surface that provide feedback during interaction. Both the button surface and a bump on the rotational base incorporate photoplethysmographic (PPG) sensors at natural contact points.

The device housing is fabricated using polylactic acid (PLA) for structural integrity, with optically transparent flexible material covering the sensor areas. The overall form factor is palm-sized with a circular profile that facilitates easy rotation while remaining comfortable to hold for extended periods.

2.2 Interaction Elements

The interaction design of CipherPal focuses on providing natural affordances while integrating sensing seamlessly into fidgeting behaviors. To better the tactile experience and data-collecting capabilities, we improved two main engagement mechanisms based on user input from our earlier prototype (Figure 2).

The rotary encoder’s built-in button has been replaced with a separate switch as part of an entirely revamped button mechanism. The tactile sensation and clicking sound produced by the new button design are more pleasing. In response to user feedback, this improvement highlights the value of both haptic and auditory feedback when fidgeting. A heartbeat sensor is included into the button’s surface beneath a transparent, flexible material that is positioned to correspond with the thumb’s position during interaction naturally.

The second heartbeat sensor, which is also wrapped in a transparent, flexible material, is located at the lowered point of the rotary element. This dual-sensor method guarantees that users’ preferred fidgeting behavior can organically be recorded.

3 Technical Implementation

The device operates in an on-demand mode, actively collecting data only during user interaction. CipherPal implements a session-based collection approach, where a session begins with the first interaction and automatically ends after 5 minutes of inactivity. When engaged, CipherPal:

- Monitors heart rate through either or both PPG sensors
- Tracks interaction patterns (button presses, rotary movements)
- Records session duration and intensity
- Aggregates data into discrete session records
- Encrypts data before temporary storage

To ensure sustainable data practices, CipherPal uses IPFS for efficient data storage, with only encrypted references stored on the blockchain. This hybrid approach significantly reduces the environmental impact typically associated with blockchain technologies while maintaining privacy and security. The approach mirrors sustainable ocean management practices, where we seek to maximize benefit while minimizing environmental impact.

The web application allows users to visualize their data through an intuitive calendar interface and manage sharing permissions, all

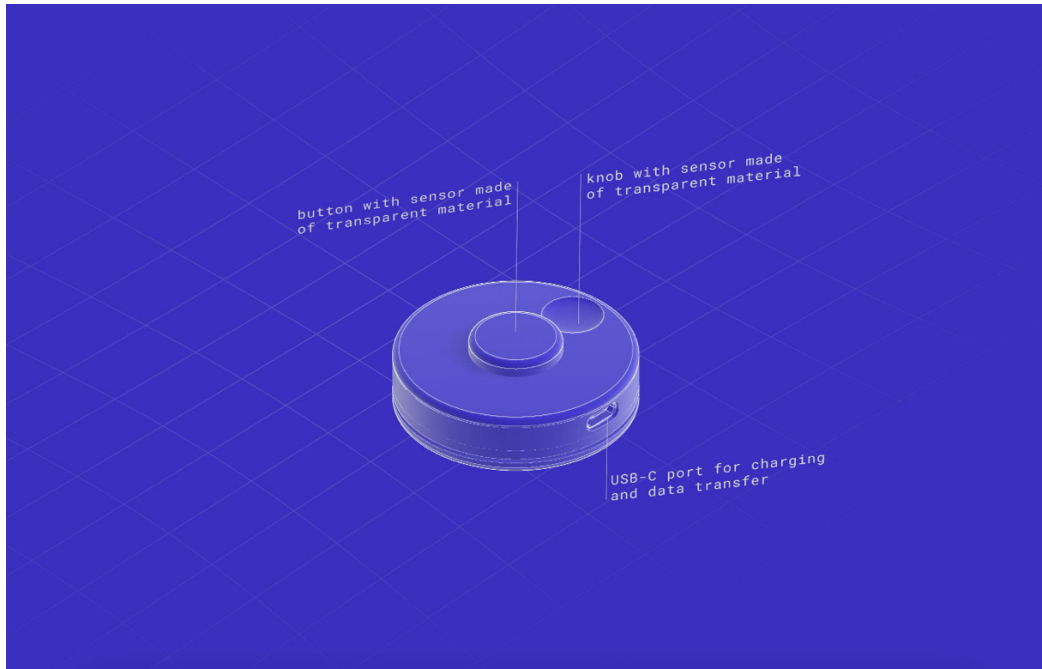


Figure 2: Schematic of Interaction Elements.

while maintaining end-to-end encryption from device to visualization (Figure 3).

4 Interactive Experience

CipherPal combines the familiar comfort of fidget toys with thoughtful digital integration. Its design aims to provide immediate tactile satisfaction and long-term insights into personal habits and patterns.

4.1 Core Interactions

CipherPal provides two different fidgeting methods, each with its tactile stimuli. Many users find the central button’s pleasing click reaction to be soothing. The rotary control offers an alternative fidgeting sensation with smooth, continuous motion in both clockwise and counterclockwise directions, giving users three distinct interaction modes (pressing, rotating clockwise, and rotating counterclockwise). Visual feedback through an integrated LED provides device status information using different colors: blue during active data collection, green when connected to the application, yellow when awaiting wallet registration, and red during disconnection or error states. Users can establish their fidgeting preferences and patterns by utilizing these encounters separately or in combination.

4.2 User Journey

When first receiving CipherPal, users begin with a simple device pairing process:

- Authenticate with blockchain wallet
- Connect device to web application
- Device LED shows magenta, indicating ready state
- Select CipherPal from available devices

- Device registers wallet address automatically
- Device generates encryption keys
- LED turns blue when setup is complete
- All future data collection is now secured

There is no need to have CipherPal linked to the app, and it functions as a stand-alone fidget device for everyday use. Users can engage with it while working in meetings or when they need to take a break. In the background, the device silently gathers interaction data.

Users can sync their data by periodically connecting CipherPal to the web application. The application lets users examine their fidgeting habits over time by presenting this data in an easy-to-use calendar layout. Their wallet credentials are used to keep all data encrypted, guaranteeing that their information is kept secret and safely saved utilizing blockchain and IPFS.

4.3 Usage Scenarios

CipherPal seamlessly adapts to the rhythm of daily life, becoming an intuitive extension of user habits. During meetings, it offers silent, discreet fidgeting options that help maintain focus throughout long sessions while quietly collecting data about potentially stressful moments. While working, CipherPal provides a welcome tangible break from screen-based tasks, supporting various fidgeting styles that complement different activities and helping users track productivity patterns over time. In personal time, the device transforms into a calming companion during leisure activities, enabling thoughtful reflection on daily patterns through the companion app while maintaining a private, secure record of personal habits and responses.

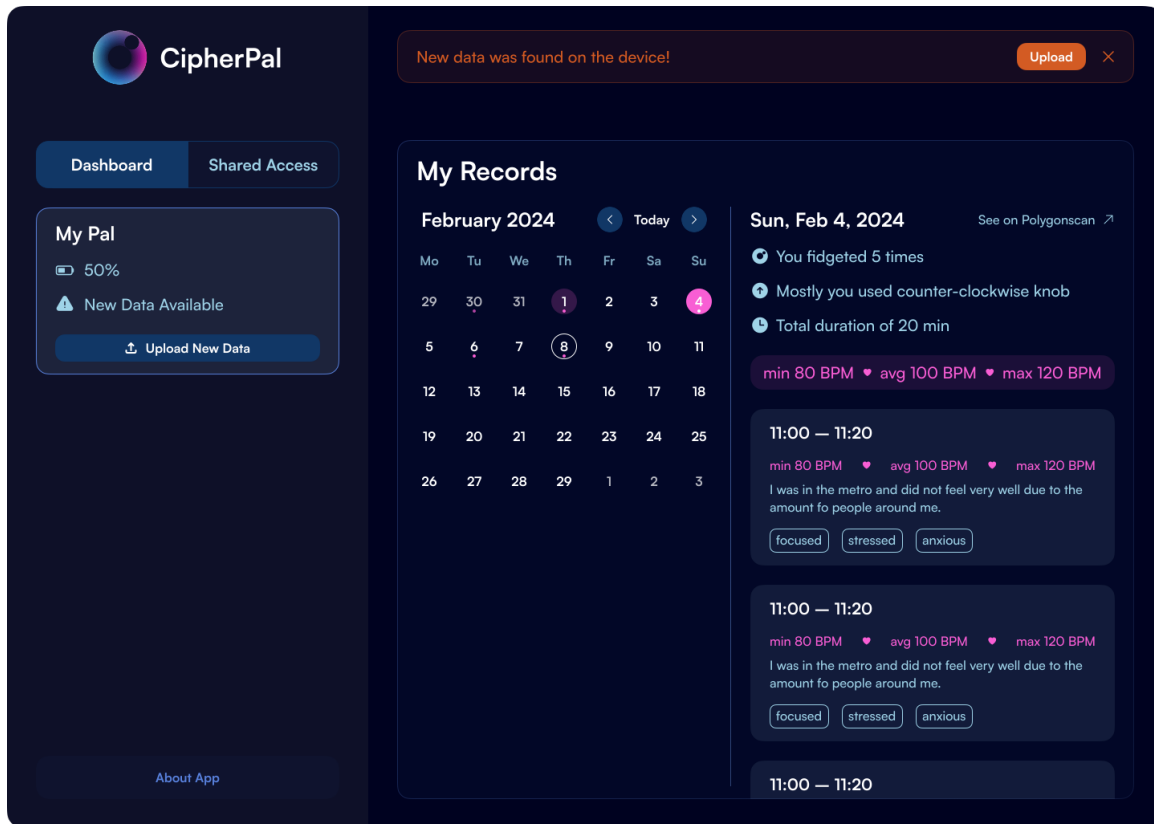


Figure 3: Dashboard Interface of the App.

Through these natural interactions, CIPHERPAL becomes a comfortable daily companion and a tool for understanding personal patterns while maintaining user privacy through blockchain technology.

5 Discussion

The creation of CIPHERPAL demonstrates how sustainability and data sovereignty concepts can be incorporated into everyday objects. The physical design reveals the potential for creating privacy-preserving devices that enhance rather than compromise user experience, while the technical implementation showcases a pragmatic approach to sustainable data management.

Just as our oceans require sustainable management practices to thrive, our personal data ecosystems need mindful approaches that balance utility with privacy and resource efficiency. By utilizing IPFS for data storage and storing only hash references on the blockchain, we significantly reduce the environmental impact typically associated with blockchain technologies.

CIPHERPAL represents a step toward more sustainable and user-controlled data collection systems. Through its dual-sensor design, custom PCB implementation, and blockchain-based security architecture, it demonstrates how privacy-preserving technology can enhance daily interactions. This balance of technical sophistication with user experience indicates a future where secure data practices

become naturally integrated into everyday objects, creating sustainable digital ecosystems that parallel our efforts to protect and preserve our ocean environments.

6 Conclusion

CIPHERPAL represents a step toward more sustainable and user-controlled data collection systems. Emphasizing physical and digital sustainability demonstrates how everyday objects can contribute to more mindful digital interactions while preserving user privacy and autonomy. Through its dual-sensor design, custom PCB implementation, and blockchain-based security architecture, CIPHERPAL shows how privacy-preserving technology can enhance rather than complicate daily interactions. This balance of technical sophistication with user experience indicates a future where secure data practices become naturally integrated into everyday objects.

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