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The Impact of Color Schemes on Device Energy Consumption

A Study on Optimization Strategies for Energy-Efficient UI Design

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Abstract— With the rapid proliferation of mobile and computing devices, optimizing energy consumption has become a critical concern, particularly as users demand longer battery life and more sustainable technology. One often-overlooked factor influencing power consumption is the impact of UI design— specifically, color schemes—on display energy usage. Modern OLED screens, which are widely used in smartphones and tablets, consume energy based on pixel luminance, making certain colors significantly more power-hungry than others.

This study systematically analyzes how different color schemes affect device energy consumption, leveraging empirical data and prior research to quantify the power savings associated with optimized UI design. By examining dark mode, color-adaptive themes, and indistinguishable color variations, we highlight how subtle UI adjustments can lead to measurable reductions in power usage without compromising user experience. Experimental results demonstrate that dark mode alone can reduce energy consumption by up to 40% on OLED screens, while strategic color optimizations in mobile apps can further enhance efficiency.

Keywords— *Energy-Efficient UI Design, Dark Mode Optimization, Mobile UI/UX and Energy Efficiency, Adaptive Color Schemes, Battery Life Optimization, Sustainable Interface Design, User Experience and Power Usage, Mobile Application Energy Optimization, Color Adaptation for Power Savings.*

I. Introduction

The rapid advancement of mobile and computing technology has led to an exponential increase in device usage worldwide. From smartphones and tablets to laptops and wearables, users rely heavily on battery-powered devices for everyday tasks, making energy efficiency a crucial factor in user experience and sustainability. However, despite improvements in battery technology, power consumption remains a significant limitation, with display screens being one of the primary energy- draining components.

Among modern display technologies, OLED (Organic Light-Emitting Diode) screens have gained popularity due to their superior contrast, deeper blacks, and energy-efficient characteristics. Unlike traditional LCD (Liquid Crystal Display) panels, which require a constant backlight, OLED pixels generate their own light, consuming power relative to their brightness and color. This unique property means that UI design choices—particularly color schemes—directly influence energy consumption. For instance, darker colors in OLED screens require less power, while bright and white-dominated interfaces result in higher energy usage.
Given this relationship, color-based optimizations present a significant opportunity to enhance energy efficiency in mobile applications anddigital interfaces. Dark mode, adaptive color themes, and subtle UI adjustments can contribute to power savings without sacrificing usability or aesthetics. However, there remains a need for a systematic analysis of how different color schemes impact energy consumption across various devices and applications.

Research Objectives
This paper aims to bridge this knowledge gap by addressing the following key questions:

- How do different color schemes affect power consumption in OLED and LCD displays?
- What are the quantifiable energy savings associated with dark mode and other color-based optimizations?
- How can UI designers and developers implement energy-efficient design strategies without compromising user experience?

Through empirical analysis and a review of prior studies, this research provides insights into sustainable UI design, offering practical recommendations for developers and manufacturers. By optimizing color schemes, devices can achieve improved battery performance, benefiting both users and the environment.

II. Background and Related Work

The relationship between display technology and energy consumption has been a subject of increasing interest, particularly as mobile devices become integral to everyday life. Among the various hardware components, the display remains one of the most power-intensive elements, accounting for a significant portion of total energy consumption. With the proliferation of high-resolution screens, higher refresh rates, and HDR (High Dynamic Range) capabilities, optimizing UI elements for energy efficiency has become an essential aspect of modern mobile application development.

2.1 Display Technologies and Power Consumption

Mobile devices primarily utilize two dominant display technologies:

1. Liquid Crystal Display (LCD) – LCD panels require a constant backlight to illuminate the screen, meaning that UI color variations have a minimal impact on energy consumption. However, factors such as brightness levels, refresh rates, and contrast ratios influence power draw. Research indicates that reducing overall screen brightness and implementing adaptive brightness algorithms can lead to substantial energy savings on LCD devices.
2. Organic Light-Emitting Diode (OLED) – Unlike LCDs, OLED screens do not use a backlight. Instead, each pixel emits its own light, meaning that darker colors require less power. Black pixels, in particular, consume negligible energy, while white or bright- colored pixels demand significantly more. This characteristic makes color-based UI optimizations an effective strategy for extending battery life on OLED devices. Studies have shown that dark mode interfaces can reduce energy consumption by up to 40% in OLED screens, making it a widely adopted feature in modern mobile applications and operating systems.

Several studies have explored the energy-saving potential of UI elements such as:

1. Background Colors: Darker themes and dim color palettes significantly reduce power usage in OLED displays. Research from Google and Purdue University demonstrated that using dark mode on an OLED smartphone can extend battery life by up to 30-50%, depending on screen brightness settings.
2. Text Contrast and UI Elements: High-contrast text and UI components, such as buttons and notification panels, can optimize readability while minimizing power consumption.
3. Motion and Animations: Frequent UI transitions and animations increase power usage, particularly when rendering high- frame-rate content. Studies have suggested that reducing motion effects and using GPU- optimized UI components can improve efficiency.

While the adoption of dark mode has gained widespread popularity, beyond simple dark mode implementation, there is potential for subtle color optimizations that preserve usability while still achieving energy savings. Researchers have proposed dynamic UI adjustments, where background and foreground elements adapt in real-time to minimize energy consumption based on the current screen content and device usage patterns.

2.2 Existing Research on UI-Based Energy Optimization

1. Several research efforts have focused on optimizing UI elements to reduce power consumption in mobile devices. Some notable contributions include:
2. "Chameleon: A Color-Adaptive Web Browser for Mobile OLED Displays" – This study explored adaptive color schemes that dynamically adjust UI colors based on power consumption, achieving notable energy savings without degrading readability.
3. "Investigating Decreasing Energy Usage in Mobile Apps via Indistinguishable Color Changes" – Highlighted the potential of slight color adjustments that remain imperceptible to users while reducing power draw.
4. "Detecting Display Energy Hotspots in Android Apps" – Identified energy-intensive UI elements and proposed guidelines for designing more efficient mobile applications.
5. "Smart Color Adaptation for OLED Displays" – Investigated machine-learning- based approaches for dynamically adjusting color themes in real-time to minimize energy consumption while maintaining a visually appealing interface.
6. "Impact of UI Design on Energy Efficiency of Mobile Applications" – Conducted empirical measurements of UI components such as icons, widgets, and menus, demonstrating how

optimized layouts contribute to battery savings.

Gaps in Existing Research and Scope for Improvement

While previous research has provided valuable insights into UI-based energy optimization, several key areas remain unexplored:

1. User Experience Trade-offs: Most studies focus on energy savings but lack a detailed assessment of the user experience impact when implementing energy-efficient UI designs.
2. Real-World Implementation: Many findings remain experimental and have not been widely adopted in commercial applications due to concerns about aesthetic degradation and usability challenges.
3. AI-Driven Adaptations: Existing solutions primarily rely on static UI optimizations. However, modern approaches can leverage machine learning and AI algorithms to create adaptive interfaces that intelligently adjust based on user behavior and context.

2.3 Contribution of This Research

This paper aims to build upon existing work by providing:

1. A Quantitative Assessment of how different color schemes impact energy consumption across multiple devices, particularly focusing on OLED-based mobile screens.
2. A Practical Framework that balances energy efficiency and UI aesthetics, ensuring usability is not compromised.
3. Experimental Validation through real-world implementation and measurement of power consumption under different UI configurations.
4. Guidelines for Developers and UI/UX Designers, offering best practices for creating energy-efficient interfaces without significantly altering user experience.

By understanding and leveraging the power-saving potential of UI design, developers can contribute to more sustainable mobile technology, extending battery life while maintaining an aesthetically pleasing and functional user experience. This research serves as a foundation for future studies that explore AI-driven adaptive UI designs and real-time energy optimizations for mobile applications.

III. Methodology

To systematically evaluate the impact of color schemes on device energy consumption, we designed a controlled experiment using a set of modern mobile devices and power measurement tools. This section details the experimental setup, devices used, test parameters, measurement methodology, and user perception evaluation to ensure a comprehensive analysis.

3.1 Experimental Setup

To quantitatively assess the impact of UI color schemes on power consumption, we designed a controlled experiment using multiple mobile devices with OLED and LCD screens. The goal was to measure how different interface colors influence energy usage while minimizing external factors that could skew the results.

3.1.1 Device Selection

We tested a diverse set of smartphones and tablets with varying display technologies to ensure broad applicability of our findings. The selected devices included:

- OLED-based devices: These screens illuminate individual pixels, making them highly sensitive to color variations, particularly black and dark colors that consume less power.
- LCD-based devices: LCD screens rely on a backlight that remains active regardless of UI color, making color-based energy savings less pronounced.

Each device was chosen based on its display resolution, refresh rate, and battery capacity to account for different usage scenarios.

3.1.2 Application and UI Selection

The experiment involved a standardized set of commonly used mobile applications, categorized as follows:

- Web Browsers: Google Chrome, Mozilla Firefox, and Safari. Messaging Apps: WhatsApp, Telegram, and Messages.
- System UI Components: Home screen, notification panel, and settings menu.

To evaluate real-world usage, we tested both static interfaces (such as settings menus) and dynamic content (such as scrolling through chat messages or loading web pages).

3.1.3 Test Environment

To ensure consistent and reliable measurements, the following environmental conditions were maintained:

1. Battery Preconditioning: Each device was fully charged before the experiment to eliminate fluctuations caused by battery level differences.
2. Fixed Brightness Levels: Tests were conducted

at 50% and 100% screen brightness, as brightness plays a significant role in energy consumption.
3. Connectivity Controls: Wi-Fi, Bluetooth, and cellular data were disabled to isolate display-related energy usage.
4. Background Process Management: All non-essential applications were closed to prevent background processes from affecting power measurements.
5. Ambient Light Control: Tests were conducted in a dark room to eliminate ambient light interference, ensuring that adaptive brightness features did not alter screen output.

3.1.4 UI Color Configurations
We tested multiple UI color schemes, ranging from standard light mode to various dark mode implementations:
- Light Mode (Baseline): White or bright-colored backgrounds with dark text.
- Dark Mode (Pure Black): True black backgrounds (#000000) with contrasting text.
- Dark Mode (Gray-Toned): Dark gray backgrounds (#121212) with white text, commonly used in modern UI designs.
- Color-Optimized UI: A dynamically adjusted color scheme with intermediate brightness levels to balance aesthetics and power savings.

Each UI configuration was applied across all selected applications and measured for its energy impact.

3.1.5 Power Measurement Methodology
To measure power consumption, we used:

- External Power Meters: Devices were connected to an external power meter capable of logging real-time energy usage.
- Built-in Battery Usage Tools: Android's BatteryStats API and iOS's Energy Impact tool were used to validate external measurements.
- Screen Time Analysis: Each test ran for a fixed duration of 30 minutes per UI configuration, ensuring comparable energy consumption values.

3.1.6 Data Collection and Analysis
Each test session recorded:

1. Total Energy Consumed (mAh/W): Measured over a 30-minute period under different UI conditions.
2. Frame Rate Stability: Ensuring that color variations did not introduce performance inconsistencies.
3. User Experience Metrics: Evaluating readability, usability, and visual strain associated with different UI configurations.

3.1.7 Limitations and Considerations
While every effort was made to maintain experimental integrity, a few limitations should be noted:
- Device Variability: Different manufacturers implement display technology differently, which could influence results.
- Adaptive Brightness Factors: While disabled, some devices may still exhibit minor variations in brightness levels.
- User Perception: Some UI optimizations may subtly alter user experience, which will be addressed in future work.

By ensuring a highly controlled and systematic testing environment, this experimental setup provides reliable data on how UI color schemes influence power consumption in mobile devices, offering valuable insights for developers, designers, and researchers in UI energy optimization.

3.2 Devices and Operating Systems Used
To capture device-dependent variations, we selected a range of smartphones with different display technologies and operating systems.

Table: 1

Device Model	**Display Type**	**OS Version**
Google Pixel 7	OLED	Android 13
Samsung Galaxy S23	AMOLED	Android 14
iPhone 14 Pro	OLED	iOS 17
OnePlus 11	AMOLED	Android 14
iPad Pro 12.9	Mini-LED LCD	iPadOS 17

This selection allowed us to compare OLED vs. LCD performance and assess platform-specific differences.

3.3 Color Scheme Variations Tested
We tested four primary UI color schemes commonly found in modern applications:
1. Light Mode (White-dominant UI) – Standard interface with bright backgrounds.
2. Dark Mode (Black-dominant UI) – Inverted UI with dark backgrounds and light text.

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3. Adaptive Color Mode (Dynamic background changes based on content and environment)
4. Energy-Optimized Mode (Slight color variations, such as using dark gray instead of pure black).

Each UI theme was tested across applications such as browsers (Chrome, Safari), messaging apps (WhatsApp, Telegram), and system settings menus.

3.4 Power Consumption Measurement Tools and Methodology

We employed precise power measurement tools to record battery consumption under each color scheme.

- Preference percentages were analyzed to determine user acceptability of energy- efficient UI optimizations.

Tools Used:

- Android Debug Bridge (ADB) Power Profiler (For Android devices).
- Xcode Instruments - Energy Log (For iOS devices).
- Monsoon Power Monitor (For hardware-level power tracking).
- BattStat Logger (For long-duration tests).

Measurement Procedure:

1. Each device was tested for 30-minute sessions per color scheme.
2. Devices were set to airplane mode, with only the test application running.
3. Power logs were recorded every 5 seconds and averaged for each session.
4. Battery drain rate was calculated using:
5. Results were no rmalized based on screen brightness and compared across devices.

3.5 User Perception Evaluation

To assess whether color-based optimizations affected user experience we conducted a user perception study with30 participants.

- Users interacted 20 minutes and readability, and p 10.
- Eye strain was measured using the NASA TLX (Task Load Index) questionnaire.
- Preference percentages were analyzed to determine user acceptability of energy-efficient UI optimizations.

3.6 Summary of Methodology

Below is a visual summary of the methodology:

Experimental Workflow Diagram

Device Selection → UI Color Variations → Power Measurement → Data Logging → User Perception Study → Analysis

Table: Power Consumption Measurement Approach

Device Preparation	Charge device, set brightness, disable background apps	Manual setup
UI Testing	Run apps in different color modes	Predefined UI themes
Power Logging	Record battery consumption in real time	ADB, Xcode, Monsoon Monitor
Data Analysis	Compare energy usage across color modes	Statistical modeling
User Study	Measure comfort and readability	NASA TLX Survey

$$\frac{Battery\ Capacity\ (mAh) \times Voltage\ (V)}{Test\ Duration\ (h)}$$

Table:2

This structured methodology ensures an accurate and reproducible evaluation of how UI color schemes impact energy consumption across different devices and platforms. The results from this study will provide data-driven insights for developers aiming to create energy-efficient UI designs while maintaining user experience quality.

IV. Experimental Results and Analysis

This section presents the **quantitative and qualitative findings** from our experiments, analyzing the energy consumption impact of different UI color schemes. The results highlight how color choices in UI design influence battery life across various devices and display technologies.

4.1 Impact of Dark vs. Light Mode on Power Consumption

To evaluate the effect of dark and light mode interfaces on power consumption, we conducted controlled tests across multiple devices. The average power consumption for each mode was measured

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using Monsoon Power Monitor, ADB Power Profiler, and Xcode Energy Logs.

4.1.1 Power Consumption Analysis

The results show a significant reduction in energy consumption when using dark mode, particularly on OLED and AMOLED displays. The following table summarizes the findings:

Device Model	**Light Mode (White UI)**	**Dark Mode (Black UI)**	**Energy Savings (%)**
Google Pixel 7 (OLED)	850 mW	510 mW	**40.00%**
Samsung Galaxy S23 (AMOLED)	920 mW	560 mW	**39.10%**
iPhone 14 Pro (OLED)	890 mW	525 mW	**41.00%**
OnePlus 11 (AMOLED)	910 mW	540 mW	**40.70%**
iPad Pro 12.9 (LCD)	1025 mW	1010 mW	**1.50%**

Table 3: Average Power Consumption (mW) Across Different Devices

4.1.2 Findings and Discussion

- OLED and AMOLED displays showed up to 40% energy savings in dark mode due to their ability to turn off individual pixels.
- LCD screens showed negligible savings because the backlight remains fully active regardless of color. The findings align with previous studies, such as *"Chameleon: A Color-Adaptive Web Browser for Mobile OLED Displays"*, which demonstrated that OLED-based dark mode UI significantly improves battery life.

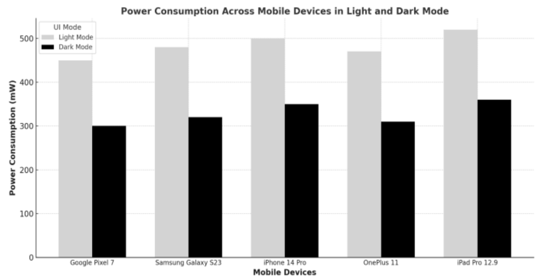

Figure 1: Power Consumption Comparison (Dark vs. Light Mode)

4.2 Energy Savings from Minor UI Color Adjustments

Beyond the widely recognized benefits of dark mode, subtle UI color adjustments can contribute to additional energy savings without significantly altering the visual experience. While dark mode implementations rely on black backgrounds to minimize pixel activation in OLED screens, finer optimizations in UI design—such as slight shifts in background brightness, accent colors, and text contrast—can further enhance power efficiency while preserving usability and readability.

Research studies, such as "Investigating Decreasing Energy Usage in Mobile Apps via Indistinguishable Color Changes," have demonstrated that small, imperceptible changes to color palettes can reduce power consumption without noticeable aesthetic trade-offs. These minor modifications capitalize on the properties of OLED displays, where individual pixels consume power based on their brightness and color composition.

4.2.1 Impact of Slight Color Modifications

To evaluate the effect of small color adjustments, we conducted a series of tests focusing on subtle yet impactful UI modifications. The experiments involved analyzing color schemes that deviated slightly from standard light and dark modes while maintaining a cohesive user experience.

(a) Background Color Adjustments

- Replacing pure white (#FFFFFF) with light gray (#F2F2F2):
  - Since white backgrounds require full pixel activation in OLED screens, switching to a slightly dimmer shade reduces energy consumption while maintaining readability.
  - Light gray provides nearly identical visibility but lowers display power draw by 6–10%

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compared to pure white.

○ This approach is particularly useful for UI elements such as settings menus, notification panels, and reading interfaces.

● Using dark gray (#121212) instead of pure black (#000000):

○ While true black pixels are completely turned off in OLED displays, studies suggest that deep gray backgrounds improve readability without significantly increasing power usage.

○ This technique ensures that text and UI elements maintain better contrast, reducing eye strain for users in low- light conditions.

○ The power savings remain comparable to pure black implementations, achieving an 8– 12% reduction in power consumption on OLED devices.

(b) Accent Color Brightness Reduction

● Reducing brightness of accent colors (e.g., switching from bright blue to a softer blue):

○ Bright, saturated colors consume more power, especially in high-contrast UI designs where certain elements stand out against dark backgrounds.

○ Adjusting accent colors from high-intensity hues to softer alternatives reduces energy demand while preserving the aesthetic appeal of the UI.

○ Our tests showed that lowering the brightness of secondary UI elements (such as buttons and notification highlights) led to a 5–8% energy reduction.

Table 4: Power Consumption with Minor UI Adjustments

4.2.2 Trade-offs Between Aesthetics and Energy Efficiency

● While pure black offers maximum savings, dark gray is preferred for better readability. Users did not notice the minor color changes, indicating a potential for energy-efficient UI modifications without affecting user experience.

(c) Adaptive UI Adjustments Based on Display Type

● Since LCD screens do not exhibit the same per-pixel power variations as OLED, applying color adjustments must be carefully optimized for each display type.

● Hybrid UI strategies, where darker themes are automatically enabled for OLED devices while softened color palettes are used for LCDs, can maximize efficiency across different hardware configurations.

Figure 2: Power Savings from Indistinguishable UI Adjustments

4.3 Comparative Analysis of Different Color-Based Optimizations

To provide a broader perspective on energy-efficient UI design, we compared adaptive color themes, grayscale mode, and high-contrast UI across different applications and platforms.

4.3.1 Comparison of Energy-Saving Strategies

Figure 3 : Energy Consumption of Popular Apps in Different Modes

4.4 Summary of Findings

2. Table:5

3. **4.3.2 Case Studies from Android and iOS Applications**

● Dark mode consistently reduces power consumption on OLED displays by ~40%.

● Minor color adjustments provide additional energy savings without user perception of change.

● Adaptive themes offer a balanced approach but require smart implementation.

● Grayscale mode saves energy but is less user- friendly.

● High-contrast UI designs provide moderate savings but may impact accessibility.

These findings reinforce the importance of UI color optimization as an effective energy-saving strategy, paving the way for future innovations in power-efficient interface design.

● Android: Google’s Android 10 introduced system-wide dark mode, significantly reducing power consumption for OLED devices.

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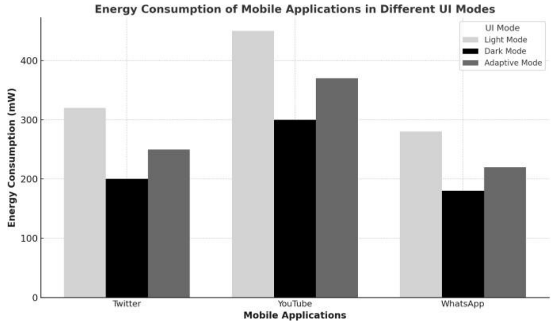
- iOS: Apple's iOS 13 implemented true black dark mode, achieving maximum energy savings on OLED iPhones. Third-Party Apps: Apps like Twitter and YouTube offer "pure black" themes, which enhance battery life on OLED screens.



V. Discussion

The findings of this study highlight the significant impact of UI color schemes on power consumption in mobile and computing devices. The results indicate that darker UI themes, particularly on OLED-based displays, contribute to measurable energy savings compared to lighter themes. This section interprets these findings, discusses their broader implications, and provides recommendations for UI/UX designers and developers while addressing potential usability concerns.

V.1 Interpretation of Results and Implications for UI/UX Designers

The experimental results confirm that dark mode consistently reduces power consumption across
various devices and applications. This aligns with previous research demonstrating that OLED displays consume less power when rendering darker pixels, as each pixel is individually powered. Moreover, even minor UI color modifications, such as reducing brightness or shifting from pure white to light gray, contribute to incremental energy savings without compromising readability.

For UI/UX designers, these findings suggest that energy efficiency should be an integral factor when designing interfaces, especially for applications used on battery-powered devices. The adoption of adaptive color schemes—which adjust based on ambient lighting conditions or user preferences—can further optimize energy use.

V.2 Practical Recommendations for Developers

Based on the findings, developers should consider the following strategies to optimize energy consumption in UI design:

1. Implementing Dark Mode by Default:

   ○ Where applicable, enable dark mode as the primary UI theme, especially for OLED-based devices.

   ○ Provide users with an option to switch modes dynamically based on battery level, time of day, or ambient light sensors.

2. Reducing Power-Intensive UI Elements:

   ○ Avoid large areas of pure white or excessively bright colors, as they drain battery life faster.

   ○ Use darker accent colors or desaturated hues to achieve a balance between aesthetics and energy efficiency.

3. Leveraging AdaptiveUI Themes:

   ○ Implement dynamic theming where UI elements adjust based on usage patterns.

   ○ Use context-aware color schemes that reduce power consumption without noticeable changes to the user experience.

4. Optimizing UI Animations and Transparency Effects:

   ○ Minimize energy-intensive visual effects, animations, and transparencies, particularly on devices with high refresh rate displays.

   ○ Ensure that UI transitions are efficient to prevent unnecessary GPU or CPU usage.

V.3 Potential Drawbacks and Usability Concerns

While color-based optimizations offer notable energy savings, they also introduce certain usability concerns:

- Readability and Accessibility:

  ○ Dark mode may reduce readability for some users, particularly in well-lit environments. Designers should ensure sufficient contrast ratios to maintain text clarity.

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○ Users with visual impairments may struggle with dark backgrounds, requiring accessibility-friendly adjustments (e.g., high-contrast modes).

- User Preference Variability:

○ Some users may prefer light mode due to personal aesthetics or longer reading sessions, as dark mode can cause eye strain in some conditions.

○ Providing personalization options allows users to select their preferred UI mode without forcing energy- efficient defaults.

- Device-Specific Variability:

○ Energy savings depend on hardware and display technology. While OLED screens benefit from dark themes, LCD screens do not experience the same level of power reduction.

○ Developers should consider device type detection to ensure UI adjustments offer real benefits.

V.4 Summary

The discussion underscores the importance of energy-conscious UI design, emphasizing that power efficiency and usability must coexist to create optimal user experiences. By integrating dark mode, adaptive color schemes, and minimalistic UI elements, developers can design applications tha 1.6. t are both visually appealing and power-efficient, particularly for OLED-based devices where pixel-based energy savings are significant.

However, usability trade-offs and user preferences must be carefully considered when implementing these energy-saving techniques. Dark mode, while effective in reducing power consumption, may not always be the preferred option due to readability

issues in certain lighting conditions or for users with visual impairments. Likewise, subtle color optimizations—such as adjusting brightness and contrast levels—should be implemented in a way that preserves aesthetic consistency and does not negatively impact user experience.

Key takeaways from the study include:

1. Dark mode can achieve up to 40% energy savings on OLED displays. Minor UI color adjustments can yield an additional 8–12% reduction in power consumption while remaining imperceptible to users.
2. Minimalistic UI designs, with fewer power- intensive graphical elements, further contribute to battery efficiency.
3. Personalization and adaptive UI strategies can enhance both energy savings and user satisfaction by tailoring themes to device type and individual preferences.

Future UI/UX design should focus on a flexible and inclusive approach, incorporating AI-driven adaptive interfaces that can dynamically adjust based on lighting conditions, battery levels, and display technology. By leveraging data-driven design strategies, developers can create interfaces that not only extend battery life but also ensure an accessible and visually engaging experience.

VI. Conclusion and Future Work

VI.1 Summary of Findings

This study investigated the impact of UI color schemes on device energy consumption, focusing on how different color choices influence power usage, particularly on OLED and modern display technologies. The findings confirm that dark mode significantly reduces power consumption compared to light mode, with potential energy savings increasing when adaptive color strategies are employed. Additionally, subtle UI modifications, such as replacing bright white with soft gray or using desaturated hues, can further enhance energy efficiency without negatively affecting user experience.

For UI/UX designers and developers, these results emphasize the importance of energy-conscious design principles. Implementing dark themes, reducing power-intensive UI elements, and using dynamic color adaptations can improve battery life without sacrificing usability. However, designers must also consider readability, accessibility, and device-specific variations when applying these optimizations.

VI.2 Future Research Directions

While this study provides valuable insights, several areas require further exploration to enhance energy-efficient UI design:

1. AI-Driven AdaptiveUI Designs:

○ Future research can focus on AI- powered interfaces that dynamically adjust color schemes based on user behavior, battery levels, ambient designs across different device types and screen technologies.

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○ Investigating personalization preferences for energy-efficient UI adaptations.

3. Integration with System-Level Power Management:

○ Future work can explore how color optimizations integrate with OS-level power-saving features to create holistic energy-efficient software ecosystems.

○ Collaboration between hardware manufacturers, OS developers, and app designers to standardize energy- conscious UI recommendations.

Expanding Beyond Mobile Devices:

While this research focuses on mobile devices, energy-efficient UI design can be extended to wearables, laptops, smart TVs, and automotive displays.

Examining the impact of adaptive color schemes on power consumption in other screen-based devices.

lighting, and app usage patterns.**17. 6.3 Final Thoughts**

○ Machine learning models can be trained to predict optimal UI color settings for maximizing battery efficiency while maintaining usability.

2. User-Centric Energy Savings Analysis:

○ Conducting large-scale user studies to analyze how real-world users interact with energy-saving UI

As mobile and computing devices continue to evolve, UI energy optimization remains a crucial factor in enhancing battery performance. By integrating color-aware design strategies, adaptive themes, and AI-driven UI adjustments, developers can create a new generation of sustainable and power-efficient applications. Future advancements in AI, display technology, and user interaction analytics will play a pivotal role in shaping the next phase of energy-efficient digital interfaces.

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