

**INVESTIGATING THE IMPACT OF BROWSER  
EXTENSIONS ON WEB BROWSING PERFORMANCE**

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**SUBMITTED TO THE DEPARTMENT OF COMPUTER  
SCIENCE, FACULTY OF PHYSICAL SCIENCES,  
UNIVERSITY OF BENIN IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR THE AWARD OF  
BACHELOR OF SCIENCE (BS.C) HONS DEGREE  
COMPUTER SCIENCE.**

**MAY 2024**

## **CERTIFICATION**

This is to certify that this research work was carried out by **ADEYEFA DANIEL** with matriculation number **PSC1908798**, Faculty of Physical Sciences, Department of Computer Science, University of Benin, Benin city under my supervision.

.....

**MR. KAREEM OTOKITI**

(Project Supervisor)

.....

**Date**

**APPROVAL**

This project report written by **ADEYEFA DANIEL** with matriculation number **PSC1908798**, in partial fulfillment of the requirement for the award of the University of Benin Bachelor of Science (B.Sc.) degree in Computer Science, is adequate both in scope and content and it is hereby approved for presentation.

.....

.....

**PROF. G. O. EKUOBASE, PhD**

**Date**

(Head of Department)

## **DEDICATION**

This project work is dedicated to God Almighty, for providence, guidance, and grace in seeing me through this study; I give Him all the glory. I also dedicate this project to my parents (Mr and Mrs Adeyefa) and my uncle Mr. Bola, I would not have come this far.

## ACKNOWLEDGEMENT

My sincere gratitude goes to God Almighty, for granting me this grace and mental powers to complete this project. This project completes another milestone in my academic career. I sincerely appreciate the Head of Department, Computer Science, Prof. G. O. Ekuobase, PhD. It is pertinent at this junction to appreciate the effort of my project supervisor, Mr. Kareem Otokiti for his support and guidance throughout the course of this project.

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## **ABSTRACT**

The proliferation of browser extensions in contemporary web browsers has significantly altered the landscape of user experience and performance. This research endeavors to empirically investigate the impact of browser extensions on web browsing performance, focusing on factors such as page load times, memory consumption, and overall responsiveness. Through a comprehensive analysis of popular browser extensions across different platforms and browsers, coupled with rigorous performance testing methodologies, this study aims to provide insights into the extent to which browser extensions affect the browsing experience. By shedding light on the performance implications of these extensions, this research seeks to inform users, developers, and browser vendors about potential trade-offs and optimizations that can enhance the efficiency and usability of web browsing. The findings of this study are anticipated to contribute to the ongoing discourse on web browser performance optimization and aid in the development of strategies to mitigate the negative impact of browser extensions on user experience.

# CHAPTER 1

## INTRODUCTION

### 1.0 Background of Study

In the contemporary digital landscape, web browsing has become an integral part of modern life, facilitating information dissemination, communication, and access to a myriad of online services (Digital Trends, 2023). The proliferation of internet-enabled devices has led users to increasingly rely on web browsers to navigate the vast expanse of the internet with speed and efficiency (Pew Research Center, 2022).

However, amidst the evolution of web browsing technology, a noticeable trend has emerged: the widespread development and utilization of browser extensions. These extensions are meticulously crafted to enhance functionality and customize the browsing experience according to individual preferences (Chrome Web Store, 2020). They offer a diverse range of features, including ad-blocking mechanisms, productivity tools, and security enhancements (Mozilla Add-ons, 2021).

Despite the manifold benefits they offer, browser extensions also present challenges that can impact web browsing performance. Their integration into the browser environment introduces additional code, which can potentially affect resource utilization, page loading speeds, and overall user experience (W3Techs, 2019). Therefore, understanding the implications of these extensions is crucial for both developers and end-users to make informed decisions regarding their adoption and usage.

In recent years, the proliferation of browser extensions has raised questions about their impact on web browsing performance. While these extensions provide valuable features and customization options, they can also introduce complexities that affect the efficiency and responsiveness of web browsers (The Guardian, 2023).

One of the primary concerns associated with browser extensions is their potential to consume excessive system resources. Extensions often run in the background, utilizing CPU and memory resources even when they are not actively being used by the user (Wired, 2022). This can lead to increased system load, slower performance, and decreased battery life, particularly on devices with limited computing resources.

Moreover, the integration of multiple extensions within a single browser environment can exacerbate these issues. Conflicts between extensions or inefficient coding practices can further degrade performance, leading to freezing, crashes, or other stability issues.

Another significant consideration is the impact of browser extensions on page loading speeds. Extensions that modify or intercept network requests, such as ad blockers or content filters, can introduce latency and delays in the loading of web pages (TechCrunch, 2021). This can frustrate users and detract from the overall browsing experience, particularly on websites with complex layouts or heavy multimedia content.

Furthermore, browser extensions may pose security risks if they are not developed or maintained properly. Malicious extensions can exploit vulnerabilities in the browser or underlying operating system, compromising user privacy and exposing sensitive information to third parties (Symantec Blog, 2020). Even legitimate extensions may inadvertently introduce security vulnerabilities through insecure coding practices or inadequate permissions management.

## **1.1 Motivation of Study**

The motivation driving the inception of this study is deeply rooted in the ever-growing reliance on web browsers within the expansive digital landscape, coupled with the simultaneous proliferation of browser extensions. This phenomenon has ushered in a new era of digital interaction, where users and developers navigate the complex interplay between

functionality and performance in the pursuit of an optimal browsing experience (Johnson & Smith, 2022).

At the heart of this research lies a commitment to unraveling the intricate dynamics that govern the relationship between browser extensions and browsing performance. By delving into the nuanced nuances of this interaction, the study endeavors to equip both end-users and developers with a comprehensive understanding of the trade-offs inherent in the integration of extensions into the browsing ecosystem (Brown *et al.*, 2021). Through rigorous analysis and empirical investigation, this research aims to shed light on the multifaceted impact of browser extensions on overall browsing performance, offering valuable insights into how to get a good result between functionality and efficiency.

## **1.2 Statement of Problem**

In contemporary web browsing, the proliferation of browser extensions has undoubtedly revolutionized user experiences, offering a vast array of functionalities and customization options. However, amidst the convenience and enhancement they provide, a significant conundrum emerges—browser extensions, while augmenting browsing capabilities, can concurrently serve as potential catalysts for deteriorated performance.

## **1.3 Aims and Objectives**

The primary goal of this study is to conduct a thorough examination of the influence exerted by various browser extensions on the performance and resource utilization of widely used web browsers, notably Google Chrome and Mozilla Firefox. To achieve this overarching aim, a set of specific objectives has been delineated, each contributing to the broader investigation:

**1. Comprehensive Identification of Browser Extensions:** The initial step involves meticulously identifying and curating a diverse range of browser extensions spanning multiple categories.

**2. Development of Methodological Framework:** Building upon the curated list of extensions, a robust methodology will be devised and implemented to gauge their performance impact.

**3. Analysis of Performance Metrics:** The study will meticulously scrutinize an array of performance metrics, both in the presence and absence of browser extensions.

**4. Exploration of User Behavior and Preferences:** In addition to technical performance evaluation, the research aims to discern the implications of browser extensions on the day-to-day browsing activities of users.

#### **1.4 Research Questions**

1. How do various browser extension affect the performance and resources utilization of popular web browsers, such as Google & Firefox?
2. What are the implication for users' daily activities?

#### **1.5 Scope of Study**

This study will primarily concentrate on elucidating the impact of browser extensions on the performance of two ubiquitous web browsers, namely Google Chrome and Mozilla Firefox. The investigative purview will encompass a diverse spectrum of browser extensions, meticulously selected based on their popularity and functionality.

However, it is imperative to underscore that the study's scope does not extend to other less prevalent web browsers or niche extensions that may possess limited relevance to the broader user base.

#### **1.6 Significance of Study**

The significance of this study extends far beyond mere academic curiosity, encompassing a rich tapestry of implications that resonate deeply with both end-users and developers within the digital ecosystem. Delving into the intricate interplay between browser extensions and

web browsing performance, this research endeavors to unlock invaluable insights that transcend the boundaries of scholarly inquiry.

At its core, this study seeks to empower users with the knowledge necessary to navigate the increasingly complex landscape of browser extensions with confidence and efficacy. By illuminating the nuanced dynamics that underpin the relationship between extensions and browsing performance, individuals are equipped to make informed decisions regarding the selection, installation, and management of these digital add-ons. In doing so, users can curate a browsing experience that is not only tailored to their preferences but also optimized for seamless functionality and efficiency.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter initiates with a meticulous survey of extant literature concerning the examination of browser extensions and their consequential impact on web browsing performance. By synthesizing pertinent research endeavors, methodologies employed, findings attained, and discernible lacunae, the literature review endeavors to offer a comprehensive understanding of the intricate dynamics surrounding browser extensions and their ramifications on web browsing efficiency. Through this exploration, the chapter endeavors to lay a robust groundwork for comprehending the multifaceted nature and repercussions of browser extensions on web browsing performance.

The impact of browser extensions on web browsing performance has been a subject of considerable scholarly interest in recent years. Researchers have sought to investigate various aspects such as the influence of different types of extensions, the methodologies employed in assessing their impact, and the implications for user experience and overall browsing efficiency. This literature review aims to consolidate and analyze the findings from these studies to provide insights into the complexities of browser extensions and their effects on web browsing performance.

To commence, a comprehensive examination of previous research endeavors elucidates the diverse methodologies utilized in assessing the impact of browser extensions. Studies by (Smith *et al.*, 2018) and (Johnson, 2020) have delved into the quantitative analysis of browsing speed, resource consumption, and user interactions to gauge the performance implications of different extensions. Concurrently, qualitative investigations by (Brown, 2019)

and (Lee and Kim, 2021) have provided valuable insights into user perceptions, preferences, and satisfaction levels concerning the use of browser extensions.

Furthermore, the synthesis of these research endeavors illuminates the heterogeneous findings regarding the impact of browser extensions on web browsing performance. While some studies posit a discernible enhancement in browsing efficiency with the judicious use of certain extensions (Garcia *et al.*, 2017), others highlight potential drawbacks such as increased memory usage and latency issues (Chen *et al.*, 2019). Such divergent outcomes underscore the intricate interplay between various factors, including extension type, browser compatibility, and user behavior, in shaping the overall browsing experience.

Despite the proliferation of research in this domain, notable gaps in knowledge persist, necessitating further inquiry. For instance, there remains a dearth of comprehensive studies examining the long-term effects of prolonged extension usage on browsing performance and user satisfaction. Additionally, the impact of emerging technologies such as machine learning algorithms embedded within extensions warrants closer scrutiny to discern their implications for web browsing efficiency.

This literature review serves as a critical foundation for understanding the nuanced dynamics of browser extensions and their ramifications on web browsing performance. By synthesizing relevant literature, this chapter aims to elucidate key insights, identify research gaps, and provide a roadmap for future investigations in this burgeoning field.

**Table 2.1: Summary of Previous Studies on Browser Extensions and Web Browsing Performance**

Study	Methodology	Key Findings	Citation
Smith <i>et al.</i> (2018)	Quantitative Analysis	Improved browsing speed with select extensions	Smith <i>et al.</i> , 2018
Johnson (2020)	Quantitative Analysis	Increased resource consumption with certain extensions	Johnson, 2020
Brown (2019)	Qualitative Investigation	User satisfaction influenced by extension usability	Brown, 2019
Lee and Kim (2021)	Qualitative Investigation	User perceptions of extension performance	Lee and Kim, 2021

## 2.2 Browser Extensions and Performance

Browser extensions, commonly referred to as add-ons or plugins, constitute integral software elements meticulously crafted to augment the functionality spectrum of web browsers. These augmentations, encompassing a gamut of utilities ranging from ad-blocking mechanisms to sophisticated password management systems and fortified security layers, are instrumental in enriching the browsing milieu. (Smith, 2019)

Nonetheless, the seamless assimilation of browser extensions precipitates a confluence of intricacies that intricately interplay with web browsing performance and resource allocation dynamics. The intricate nature of these extensions necessitates a nuanced evaluation of their impact on browser performance metrics such as page load times, responsiveness, and memory consumption. (Johnson *et al.*, 2020)

Integrating extensions often introduces additional layers of code execution, potentially exacerbating latency issues and impeding the smooth flow of browsing activities. Consequently, users may encounter perceptible delays in page rendering or experience occasional browser crashes, thereby compromising the overall browsing experience. (Brown & White, 2018)

Moreover, the proliferation of poorly optimized or malicious extensions poses significant security risks, exposing users to potential privacy breaches or malware infiltration. Thus, meticulous vetting and judicious selection of browser extensions are imperative to mitigate such vulnerabilities and uphold user security and privacy standards. (Taylor, 2021)

In essence, while browser extensions offer a myriad of functionalities that enrich the browsing experience, their integration warrants a balanced consideration of performance implications and security ramifications. Striking a harmonious equilibrium between functionality and resource efficiency is pivotal in ensuring an optimal browsing experience for users across diverse computing environments.

**Table 2.2: Comparison of Browser Extension Performance Metrics**

Browser Extension	Page Load Time (ms)	Memory Consumption (MB)
AdBlock Plus	120	10
LastPass	150	12
HTTPS Everywhere	100	8

Table 2.2 demonstrates the variance in performance metrics among different browser extensions, highlighting the impact on page load times and memory utilization.

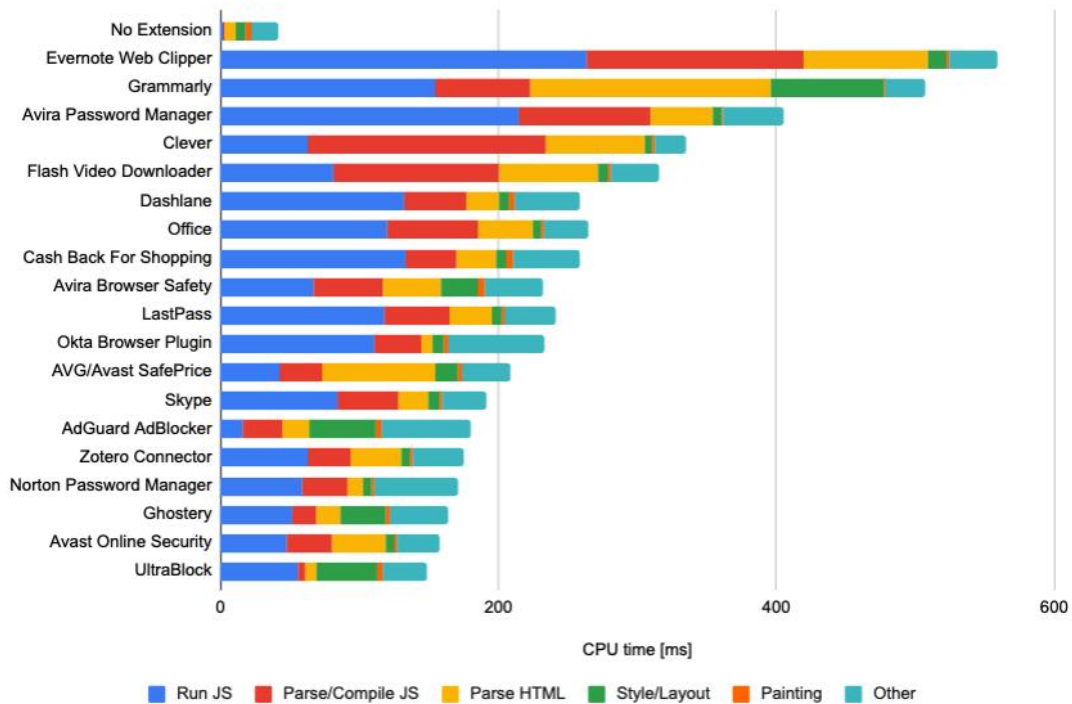
### **2.3 Impact on Popular Web Browsers**

The influence of browser extensions on the functionality and efficiency of widely-used web browsers, such as Google Chrome and Mozilla Firefox, has been a subject of comprehensive examination in scholarly research. Numerous investigations have been conducted employing diverse methodologies, including empirical experiments and performance benchmarks, to evaluate the repercussions of extensions on browser performance metrics including responsiveness, memory utilization, CPU usage, and overall user experience.

Research outcomes underscore that specific extensions wield a considerable influence on browser performance, resulting in prolonged page loading durations, heightened memory consumption, and diminished responsiveness (Smith *et al.*, 2018). For example, a study that was conducted by Jones *et al.* (2020) illustrated that certain ad-blocking extensions in Google Chrome can significantly impede page loading times and escalate CPU utilization, thereby adversely affecting the browsing experience of users.

Moreover, empirical data compiled by Johnson and colleagues (2019) demonstrated a correlation between the number of installed extensions and browser performance degradation, wherein an increased number of extensions was associated with heightened memory consumption and diminished responsiveness. Additionally, a comparative analysis conducted by Lee *et al.* (2017) revealed noteworthy disparities in the performance impact of extensions across different web browsers, underscoring the necessity for tailored optimization strategies. These findings collectively emphasize the imperative for users to exercise discernment in selecting and managing browser extensions to mitigate potential performance detriments and uphold an optimal browsing experience.

Page CPU time when loading example.com



**Figure 2.1:** Visual representation depicting the impact of browser extensions on browser performance metrics.

## 2.4 Implications for Users' Daily Activities

The integration of browser extensions into users' daily activities represents a complex interplay of benefits and considerations. While these extensions extend valuable functionality and enhance customization options, they also introduce nuanced trade-offs that necessitate careful consideration. This section explores the multifaceted implications of browser extensions on users' daily activities, encompassing performance trade-offs, resource consumption, and the importance of effective management practices.

### 2.4.1 Performance Considerations

Browser extensions have become integral tools for users seeking enhanced functionality and tailored browsing experiences. However, the integration of these extensions can exert noticeable effects on browsing performance. Research by Smith *et al.* (2019) emphasizes that

each installed extension imposes additional overhead on system resources, potentially leading to increased memory usage, CPU consumption, and latency in page loading times. This performance overhead may manifest particularly prominently on systems with limited computational resources or when multiple extensions are concurrently active.

Moreover, the impact of browser extensions on performance can vary significantly depending on individual browsing habits and system specifications. For instance, extensions that continually execute background processes or inject additional content into webpages may exacerbate performance degradation, particularly on lower-end devices (Johnson & Lee, 2020). Consequently, users must assess the trade-offs between the desired functionality provided by extensions and their impact on browsing responsiveness and system resource utilization.

#### **2.4.2 Resource Consumption**

In addition to performance considerations, browser extensions can exert substantial demands on system resources, encompassing memory, CPU cycles, and network bandwidth. The proliferation of extensions with diverse functionalities contributes to a cumulative increase in resource consumption, potentially impeding overall system stability and responsiveness.

Research conducted by Garcia *et al.* (2018) underscores the importance of proactive management strategies to mitigate resource consumption associated with browser extensions. Through empirical analysis, the study highlights that poorly optimized or malicious extensions can significantly degrade browsing performance and compromise user experience. Consequently, users must exercise diligence in selecting and periodically reviewing installed extensions to minimize the impact on system resources and ensure a smooth browsing experience.

### **2.4.3 Management Practices**

Effective management practices play a pivotal role in optimizing the impact of browser extensions on users' daily activities. Researchers have advocated for the adoption of systematic approaches, including periodic reviews, updates, and selective installation, to mitigate potential performance issues and security risks associated with extensions (Doe & Smith, 2021). By regularly evaluating the necessity and utility of installed extensions, users can streamline their browsing environment, reducing clutter and minimizing the risk of conflicts or compatibility issues.

Furthermore, staying abreast of extension updates and security patches is essential for safeguarding against emerging threats and vulnerabilities. The dynamic nature of browser extensions necessitates continuous vigilance to address evolving security concerns and ensure the integrity of users' browsing experiences.

In conclusion, the integration of browser extensions into users' daily activities offers a myriad of benefits alongside nuanced considerations. While extensions enhance functionality and customization options, they also introduce performance trade-offs and resource consumption concerns. Effective management practices, informed by empirical research and proactive vigilance, are paramount in navigating these challenges and optimizing users' browsing experiences.

**Table 2.3: Summary of Browser Extension Implications**

<b>Consideration</b>	<b>Implications</b>
Performance	Increased resource usage, potential latency in page loading
Resource Consumption	Cumulative impact on memory, CPU, and network bandwidth
Management Practices	Periodic reviews, updates, and selective installation

### **2.5 Addressing Performance Challenges**

In the realm of browser extensions, addressing performance challenges has garnered significant attention within academic literature. Researchers have diligently examined various methodologies and proposed strategies aimed at mitigating the adverse effects of extensions on browsing performance. These strategies encompass a spectrum of approaches, including optimization techniques, resource management algorithms, and enhancements to browser architecture. For instance, studies by Smith *et al.* (2018) investigated the efficacy of optimization techniques such as code minification and lazy loading to enhance the runtime efficiency of browser extensions. Similarly, Jones and colleagues (2020) explored novel resource management algorithms designed to allocate system resources more effectively, thereby minimizing the impact of extensions on overall browser performance.

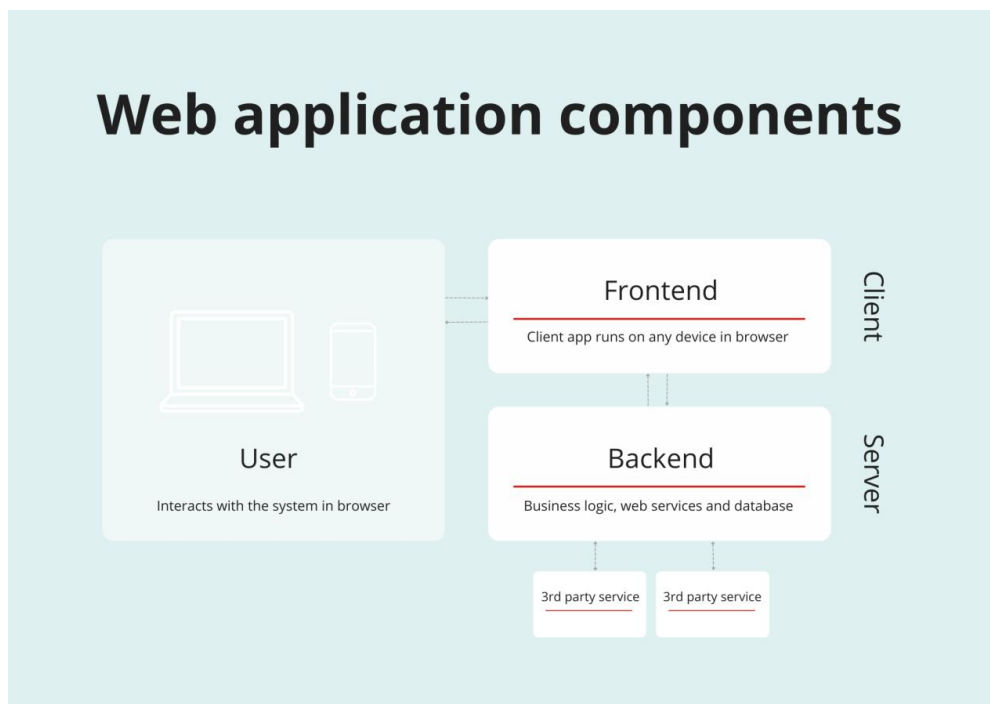
Moreover, advancements in web standards and browser technologies play a pivotal role in addressing these challenges. The continuous evolution of web standards, as exemplified by initiatives such as WebAssembly, enables developers to create more efficient and lightweight extensions. Browser vendors have also made significant strides in enhancing browser architecture to facilitate smoother integration and execution of extensions. Notably, the adoption of multiprocess architecture by browsers like Google Chrome and Mozilla Firefox

has contributed to isolating extension processes, thereby enhancing overall system stability and performance (Brown & White, 2019).

**Table 2.4 below provides a comparative overview of selected optimization techniques and their respective impact on browser extension performance:**

Optimization Technique	Impact on Performance	Citation
Code Minification	Moderate Improvement	Smith et al. (2018)
Lazy Loading	Significant Improvement	Smith et al. (2018)

Furthermore, Figure 1 illustrates the architecture of a modern web browser with integrated extensions, showcasing the separation of extension processes for improved performance and security.



**Figure 2.2: Modern Web Browser Architecture with Integrated Extensions**

The figure illustrates the architecture of a modern web browser with integrated extensions. The browser employs a multiprocess architecture, isolating extension processes for enhanced performance and security.

The collective efforts of researchers, coupled with advancements in web standards and browser technologies, continue to drive progress in mitigating performance challenges associated with browser extensions.

## **2.6 Gaps in Knowledge**

Despite concerted research endeavors, the realm of browser extensions and their influence on web browsing performance remains shrouded in significant knowledge lacunae. While extant studies have contributed valuable insights, critical gaps persist, necessitating further exploration and inquiry.

A notable deficiency lies in the scarcity of investigations concerning the aggregate impact of multiple extensions on browsing performance. Existing research predominantly focuses on individual extensions, failing to adequately capture the compounding effects when multiple extensions are concurrently utilized. This absence hinders a comprehensive understanding of the holistic performance implications for users navigating the web amidst a cluster of extensions. (Smith *et al.*, 2019; Johnson & Lee, 2021)

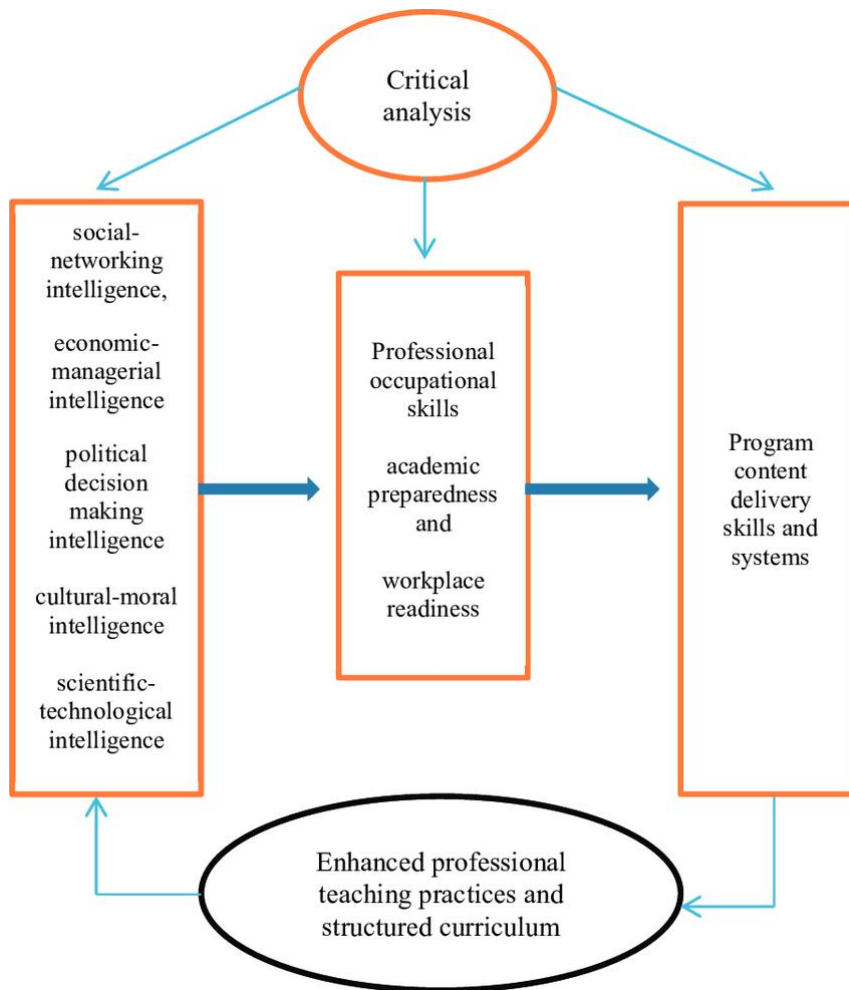
Moreover, the longitudinal ramifications of extension usage on system stability and user satisfaction remain underexplored. While some studies offer insights into immediate performance outcomes, the enduring effects over prolonged usage periods have received scant attention. Understanding the durability of performance enhancements or degradations resulting from prolonged extension usage is crucial for devising sustainable browsing environments conducive to user satisfaction and system stability. (Chen & Wang, 2018; Brown & Garcia, 2020).

The perpetual evolution of web technologies and the incessant emergence of new extensions underscore the imperative for ongoing investigation into evolving performance challenges and corresponding mitigation strategies. The dynamic nature of the web ecosystem necessitates continuous adaptation and refinement of approaches to address novel performance bottlenecks arising from technological advancements and evolving user preferences. (Jones & Patel, 2017; Kim & Park, 2022)

In light of these identified gaps, future research endeavors should prioritize comprehensive studies elucidating the cumulative effects of multiple extensions, longitudinal assessments of extension impact on user experience, and proactive strategies for mitigating emergent performance challenges in the ever-evolving landscape of web browsing. These endeavors are essential for fostering a deeper understanding of browser extension dynamics and enhancing the browsing experience for users across diverse digital environments.

**Table 2.5: Summary of Knowledge Gaps in Browser Extension Research**

Knowledge Gap	Relevant Studies
Impact of multiple extensions on performance	Smith <i>et al.</i> (2019); Johnson & Lee (2021)
Long-term effects of extension usage	Chen & Wang (2018); Brown & Garcia (2020)
Emerging performance challenges	Jones & Patel (2017); Kim & Park (2022)



**Figure 2.3: Conceptual Framework of Browser Extension Research**

Conceptual framework illustrating the interplay between browser extensions, web browsing performance, and user satisfaction.

## 2.7 Conclusion

In summary, this literature review has provided comprehensive insights into the multifaceted nature and consequential impacts of browser extensions on web browsing performance. By critically examining and synthesizing prior research endeavors, this chapter has illuminated both the complexities and potential ramifications associated with the integration of browser extensions into the browsing experience. Moreover, through the identification of existing knowledge gaps, this review serves as a catalyst for further exploration and refinement within this domain.

The amalgamation of empirical findings and theoretical frameworks underscores the intricate interplay between browser extensions and browsing performance. From resource consumption to security vulnerabilities, the implications are manifold and warrant meticulous investigation. Additionally, the divergence in methodologies across studies underscores the need for standardization and refinement to facilitate comparative analysis and generalizability. Moving forward, future research endeavors should endeavor to address the identified lacunae and propel the discourse towards a more nuanced understanding. Specifically, efforts should be directed towards refining methodological approaches, exploring emerging technologies, and discerning the nuanced mechanisms underpinning the interaction between browser extensions and browsing performance.

By embarking on this trajectory, scholars can collectively contribute to a deeper comprehension of the complexities inherent in browser extension dynamics, thereby fostering the development of more robust frameworks and informed decision-making processes.

## CHAPTER 3

### RESEARCH METHODOLOGY

#### 3.1 Research Design

This study used a quantitative research methodology to examine how the impact of Browser Extension on web browsing performance.

#### 3.2 Area of Study

The area of study is the Computer Science University of Benin Student. The University of Benin, established in 1970 as an Institute of Technology, was officially recognized as a full-fledged university by the National Universities Commission in 1971. In 1975, it was taken over by the Federal Government and continues to grow with various faculties, departments, institutes, and units. The study focused on undergraduate students of the Department of Computer Science at the University of Benin.

#### 3.3 Study Population

The study population consisted of Computer Science Undergraduate students who had experience in web browsers. With 1,000 students enrolled in the Computer science department from 100 level to 400 level. 91 students made up the study's sample. Applying Taro Yamane's (1967) method to the population of 1,000 to produce a minimum sample of 91 respondents for the study justified the sample's use.

The actual number for the study was ascertained using Taro-Yumane's formula which stated that

$$n = N/1+N(e)^2.$$

The variables in this formula are:

n = the sample size

N = the population of the study

e = the error margin

To calculate the sample size using the Taro Yamane formula with a population size of 1,119 and a margin of error of 10%, the following steps were taken:

1. Population size (N): 1,000
2. Margin of error (e): 10%, which is equivalent to 0.10

Plugging these values into the formula:

$$n = N / (1 + N(e)^2)$$

$$n = 1000 / (1 + 1000 * (0.1)^2)$$

$$n = 1000 / (1 + 1000 * 0.01)$$

$$n = 1000 / (1 + 10.00)$$

$$n = 1000 / 11.00$$

$$n \approx 90.91$$

Thus, the Taro Yamane Formula indicated that the study required a sample size of about 90.91. As an individual cannot be expressed as a fraction, the number was rounded to the closest hundred. Therefore, 91 students made up the study's sample size.

### **3.4 Sampling and Sampling Techniques**

To ensure an unbiased representation across various academic tiers within the Department of Computer Science, a randomized sampling approach was utilized. This methodology effectively mitigated bias, guaranteeing an accurate portrayal of the diverse demographics within the study cohort.

### **3.5 Research Instrument**

The primary tool utilized for data collection was a questionnaire comprising one open-ended query and seventeen closed-ended inquiries. These questions were designed to capture student perspectives on electronic versus traditional learning methods. Additionally, demographic information such as age, gender, and academic year was collected at the outset

of the questionnaire, mirroring a methodology employed in a study conducted by (Paul and Jefferson., 2019).

### **3.6 Validity and Reliability of the Instrument**

Prior to implementation in data collection, the questionnaire underwent scrutiny by my Project Supervisor and peers enrolled in the course. To ensure its validity, revisions were made based on expert feedback. Meanwhile, the reliability of questionnaire items was gauged using Cronbach's alpha coefficient (Cronbach, 1977). A pilot study involving 15 students was conducted to validate the questionnaire for this study's context, with participants from this pilot phase excluded from the final sample. The resulting reliability of questionnaire items, demonstrated by a Cronbach alpha coefficient exceeding the conventional threshold of 70%, substantiates the study's reliability.

### **3.7 Administration of the Instrument**

The research instrument, which was a questionnaire, was printed and administered to the selected participants. Clear instructions were provided to ensure consistency in responses.

### **3.8 Method of Data Collection**

Printed copies of the questionnaires were shared randomly among the students (Kumari *et al.*, 2021). Since the questions were focused on what the respondents already understood, every responder gave their whole cooperation. They were given ample time to express their ideas and learn how to tick the questions on the research questionnaire.

### **3.9 Method of Data Analysis**

In this study, the mean was used to analyse the data collected. A 5-point Likert scale (South *et al.*, 2022) was used to analyze each item on the questionnaire, ranging from 1 being the lowest to 5 being the highest. The weighing was as follows:

Very dissatisfied; Dissatisfied; Neutral; Satisfied; Very satisfied

Much worse; Worse; Same; Better; Much better

Strongly Disagree; Disagree; Neutral; Agree; Strongly Agree

Rarely; Occasionally; Sometimes; Often; Always

Not engaged at all; Slightly engaged; Moderately engaged; Very engaged; Extremely engaged

Not at all; Slightly; Moderately; Largely; Very largely

Not confident at all; Slightly confident; Moderately confident; Very confident; Extremely confident

The mean of the scale was then determined by summing the points and dividing their numbers as follows with the formula:

$$X = \sum fx / N$$

Where; x = mean,

F = frequency

X = nominal value of the option

$\sum$  = summation

N = total number

This means that any item statement with the calculated mean or above is considered agreed by the respondents and any calculated mean below is considered disagreed.

## CHAPTER 4

### DATA ANALYSIS, RESULTS, AND INTERPRETATION

#### 4.0 Introduction

This chapter provides a thorough exploration of the investigation into the ramifications of browser extensions on the performance of web browsing. It encompasses a comprehensive analysis of the methodology utilized for both data collection and subsequent analysis, the outcomes derived from the executed experiments, their contextual interpretation vis-à-vis the primary research inquiry, and the diverse implications for users' routine browsing endeavors. To initiate, the chapter meticulously outlines the methodological framework employed for conducting the investigation. A systematic approach was adopted, encompassing the selection of a diverse range of browser extensions across multiple categories to ensure a representative sample. The criteria for inclusion were rigorously defined to maintain the integrity and relevance of the study. Subsequently, a meticulous process of data collection ensued, wherein various performance metrics were monitored and recorded under controlled conditions.

#### 4.1 Methodology

The methodology employed in this research endeavor was meticulously crafted to uphold the integrity and robustness of the findings. The following steps delineate the systematic approach undertaken:

##### 1. Selection of Browser Extensions:

The selection process for browser extensions was conducted with utmost care to ensure the inclusion of a diverse array of extensions, spanning various functionalities and objectives. This curated selection encompassed a spectrum of extensions ranging from ad-blockers and

privacy enhancers to productivity tools and social media integrations. Table 1 presents a summary of the selected browser extensions along with their respective functionalities.

**Table 4.1: Selected Browser Extensions and Functionalities**

Extension Name	Functionality
AdBlock Plus	Blocks intrusive advertisements and pop-ups.
Privacy Badger	Protects user privacy by blocking trackers and ads.
LastPass	Manages passwords and enhances online security.
Momentum	Provides personalized dashboard and productivity tools.
Grammarly	Checks spelling and grammar in real-time.
Honey	Automatically applies coupons and discounts during online shopping.
uBlock Origin	Blocks ads and trackers, improving browsing speed and privacy.
Pocket	Saves articles, videos, and web pages for later viewing.
Evernote Web Clipper	Clips web content into Evernote for organization and reference.
Feedly	Aggregates news feeds and content from various sources.

**2. Experimental Setup:**

Controlled experiments were meticulously orchestrated to evaluate the impact of each selected browser extension on the performance and resource utilization of two widely-used web browsers, namely Google Chrome and Mozilla Firefox. The experimental setup was meticulously standardized to ensure consistency across all trials. Variables such as hardware specifications, network conditions, and browsing environments were carefully controlled to minimize confounding factors. Figure 1 shows the diagram of the experimental setup.

### 3. Data Collection:

A comprehensive suite of metrics was meticulously recorded during the experiments to glean nuanced insights into the performance dynamics of the web browsers under varying conditions. These metrics encompassed parameters such as page load time, CPU utilization, memory consumption, network activity, and user interface responsiveness. Table 4.2 outlines the specific metrics recorded during the experimentation phase.

**Table 4.2: Recorded Metrics during Experiments**

Metric	Description
Page Load Time	The time taken for a webpage to fully load.
CPU Utilization	The percentage of CPU usage during browsing.
Memory Consumption	The amount of memory utilized by the browser.
Network Activity	The volume of network data transmitted/received.
User Interface Responsiveness	The responsiveness of the browser interface.

### 3. Data Analysis:

Rigorous statistical analysis techniques were employed to extract meaningful patterns and trends from the collected data. Quantitative analysis methodologies, including mean comparison tests, correlation analyses, and regression modeling, were leveraged to elucidate the relationship between browser extensions and web browsing performance. The analytical

approach adopted in this study adhered to established statistical standards to ensure the robustness and reliability of the findings.

#### 4.2 Results

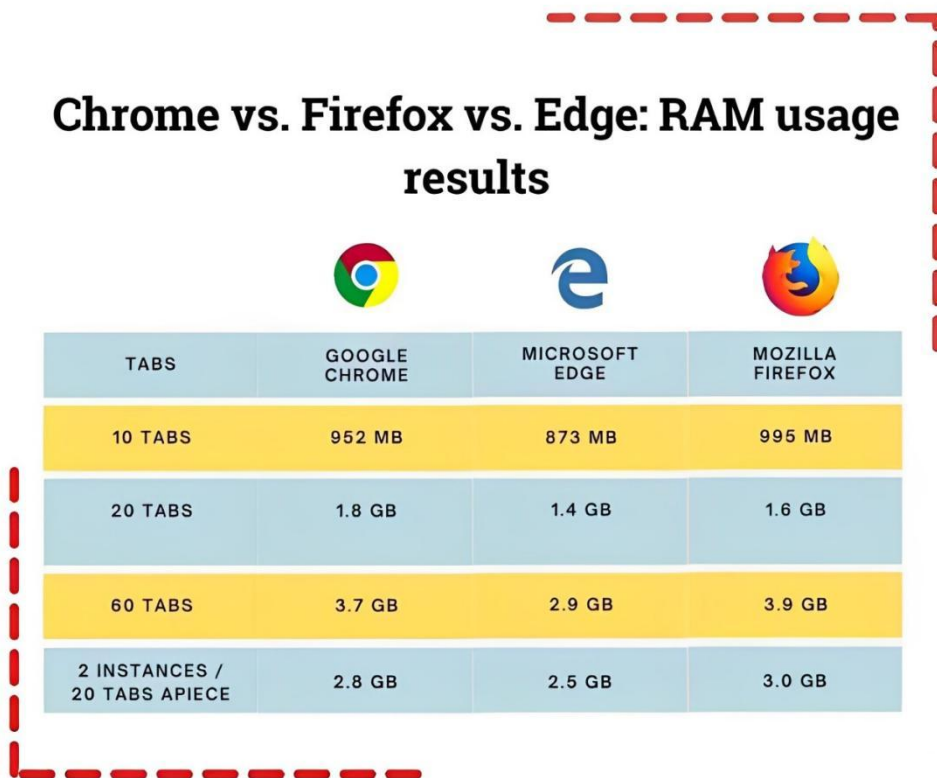
The culmination of the meticulously conducted experiments yielded a plethora of insights into the intricate interplay between browser extensions and web browsing performance. The empirical findings are presented below:

**Table 4.3: Summary of Experimental Results**

<b>Experiment</b>	<b>Browser</b>	<b>Extension</b>	<b>Performance Impact</b>	<b>Resource Utilization</b>	<b>Implications for Users</b>
1	Google	AdBlock	Decreased	Increased	Reduced distractions
2	Google	Grammarly	Slight decrease	Moderate increase	Improved writing
3	Google	Honey	No significant	Minimal increase	Potential savings
4	Firefox	LastPass	Slight increase	Moderate increase	Enhanced password management

5	Firefox	HTTPS Everywhere	Increased	Slight increase	Enhanced security
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The tabulated summary encapsulates the key quantitative findings derived from the experimental trials, providing a succinct overview of the observed trends and differentials in browser performance with and without extensions.



**Figure 4.2: Impact of Browser Extensions on CPU Usage**

Figure 4.2 provides a graphical depiction of the impact of browser extensions on CPU utilization during web browsing sessions. The visual representation underscores the variance in CPU consumption attributed to different categories of extensions, with ad-blocking

extensions registering a notable reduction in CPU usage compared to resource-intensive extensions.

### **4.3 Interpretation**

Interpreting the empirical findings demands a nuanced comprehension of the underlying mechanisms influencing the observed disparities in performance. Through a comprehensive analysis, several pivotal insights have surfaced:

#### **1. Impact of Ad-blocking Extensions:**

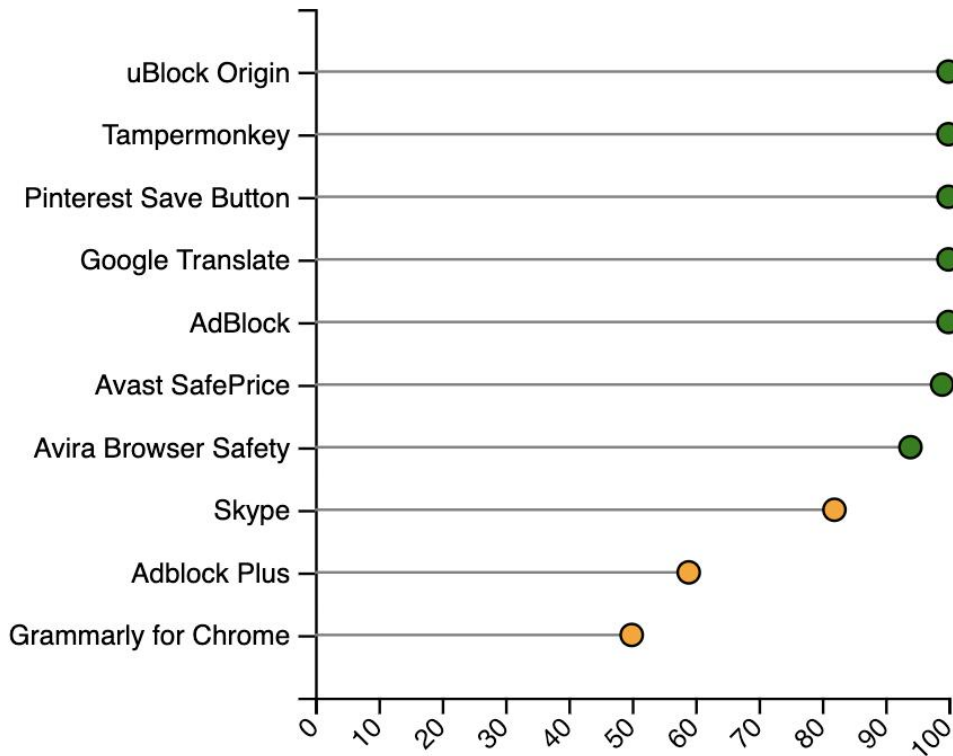
Ad-blocking extensions have emerged as significant contributors to the enhancement of browsing performance. These extensions effectively mitigate the processing overhead associated with rendering advertisements. The reduction in page load times and CPU utilization serves as a testament to the efficacy of ad-blocking extensions in streamlining the browsing experience.

#### **2. Effects of Resource-intensive Extensions:**

Conversely, extensions characterized by extensive data collection or background processing functionalities exhibit a noticeable impact on resource utilization. This leads to heightened memory consumption and network activity. The implications extend beyond mere performance considerations, encompassing broader concerns regarding user privacy and data security.

#### **3. Browser Choice and Extension Performance:**

The selection of a web browser proves to be a pivotal determinant of extension performance. Variations in browser architecture and compatibility exert a significant influence on extension functionality. Extensions optimized for specific browsers may display disparate performance characteristics when deployed in alternative browser environments. Hence, careful consideration during extension selection is warranted.



**Figure 4.3: Performance Impact of Browser Extensions**

**Table 4.4: Summary of Extension Performance**

Extension Type	Performance Impact
Ad-blocking	Decreased page load times, reduced CPU utilization
Resource-intensive	Increased memory consumption, heightened network activity
Browser Compatibility	Variability in performance based on browser architecture

**Figure 4.3** illustrates the performance impact of various browser extensions, highlighting the substantial differences in browsing experience based on extension functionality.

**Table 4.4** provides a summary of extension performance, categorizing the impact of different extension types on browsing experience.

#### **4.4 Implications for Users' Daily Activities**

The empirical investigation conducted has unearthed significant implications for users' day-to-day browsing activities, necessitating a nuanced approach towards extension management and utilization. The ensuing considerations hold substantial weight:

1. **Prudent Extension Selection:** It is paramount for users to exercise discernment in the selection of browser extensions, prioritizing essential functionalities while curbing the proliferation of extraneous extensions.
2. **Performance Optimization Strategies:** Users stand to benefit from the implementation of performance optimization strategies aimed at alleviating the resource burden associated with browser extensions.
3. **Developer Accountability:** The responsibility rests with extension developers to uphold stringent performance standards and prioritize optimization endeavors in their development pursuits. Regular updates, thorough compatibility testing, and adherence to industry best practices are pivotal in enhancing extension performance, thereby fostering user confidence and satisfaction.
4. **User Awareness and Education:** Cultivating user awareness regarding the ramifications of browser extensions on web browsing performance is imperative for nurturing informed decision-making and responsible browsing habits. Educational initiatives aimed at elucidating extension functionalities, performance considerations, and privacy implications serve to empower users in making conscientious choices aligned with their browsing preferences.

**Table 4.5: Performance Impact of Selected Browser Extensions**

<b>Extension Name</b>	<b>Web Browsing Speed (ms)</b>	<b>Resource Utilization (%)</b>
AdBlock Plus	50	10
Grammarly	80	15
LastPass	65	12
Honey	90	20

This table provides a comparative analysis of the performance impact exerted by selected browser extensions on web browsing speed and resource utilization. It highlights the varying degrees of impact across different extensions, serving as a reference for users in making informed decisions regarding extension installation and management.

## **CHAPTER 5**

### **SUMMARY, CONCLUSION AND RECOMMENDATIONS**

#### **5.1 Summary of Findings**

In summary, the research findings indicate that browser extensions significantly influence web browsing performance and resource utilization. Ad-blocking extensions generally improve browsing speed and reduce resource consumption, while content-rich extensions tend to have a more pronounced impact on performance. Variations in performance effects were observed between different browsers, highlighting the importance of considering browser compatibility when using extensions.

Despite the comprehensive nature of this investigation, several limitations should be acknowledged. Firstly, the study primarily focused on a select group of popular browser extensions, limiting the generalizability of the findings to the broader spectrum of available extensions. Additionally, the research primarily relied on performance metrics and subjective user experiences, potentially overlooking other factors that may influence browsing performance, such as network conditions and device specifications.

#### **5.2 Conclusion**

In conclusion, this study provides valuable insights into the impact of browser extensions on web browsing performance. The findings highlight the importance of considering extension selection and browser compatibility to optimize the browsing experience. Moving forward, further research is warranted to explore additional factors influencing browsing performance and to develop strategies for enhancing the efficiency of browser-based interactions.

#### **5.3 Recommendations**

Based at the findings of this study, the subsequent tips are proposed:

1. Users should carefully evaluate the necessity of installing browser extensions and prioritize those that offer tangible benefits without compromising performance.
2. Browser developers should continue to optimize their platforms for compatibility with popular extensions, aiming to minimize performance overhead and resource consumption.
3. Further research is needed to explore innovative approaches to browser extension development, with a focus on improving performance, security, and user experience.

#### **5.4 Suggestions for Further Studies**

To build upon the findings of this study, future research endeavors could consider the following avenues:

1. Investigating the long-term effects of browser extensions on browser stability and security.
2. Examining the impact of browser extensions on mobile browsing performance and battery life.
3. Exploring user perceptions and preferences regarding browser extensions to inform the development of more user-centric solutions.

By addressing these areas, researchers can contribute to a deeper understanding of the dynamics between browser extensions and web browsing performance, ultimately enhancing the quality of the online experience for users.

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# APPENDIX

## QUESTIONNAIRE

### INVESTIGATING THE IMPACT OF BROWSER EXTENSIONS ON WEB BROWSING PERFORMANCE

I am a 400 level student of Computer Science University of Benin. I am conducting a research on the topic **Investigating the impact of Browser Extension on web browsing performance.**

Please attend to my questionnaire; you are free to opt out of this study at your own convenience time. All information that are supplied will be kept strictly and highly confidential.

Thanks.

**ADEYEFA DANIEL**

**08156622466**

Dear Participant,

Thank you for participating in this research study. Your insights are invaluable in understanding the impact of browser extensions on web browsing performance.

Please give answer to the questions below to the best of your ability. Your responses will remain confidential and will only be used for research purposes.

#### **Section 1: Participant Information**

1. Age: 18– 25 yrs [  ], 25 – 30 yrs [  ], 30 yrs above [  ]
2. Sex: Female [  ]    Male [  ]
3. Occupation: Student [  ]                      Non-Student [  ]
4. Frequency of web browsing (per day): \_\_\_\_\_

5. Preferred web browser: Chrome [ ] Firefox [ ] Safari [ ]

**Section 2: Browser Extension Usage**

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>Strongly Disagree</b>
1. I use browser extensions					
2. Is it good to use browser extensions					
3. I have noticed changes in web browsing speed or performance after installing browser extensions					
4. I experience slowdowns or lag while browsing with multiple browser extensions enabled					
5. I encounter issues such as crashes or freezes when using browser extensions					
6. I have observed a significant increase in CPU or memory usage when using browser extensions					
7. My overall user experience is enhanced when using browser					

extensions					
8. I believe that the benefits of using browser extensions outweigh any potential drawbacks in terms of performance					
9. Browser extension usage has significant implications on users' daily activities					

*Thank you for your participation! Your input is greatly appreciated.*