Quantifying Cognitive Load during Online Reading Tasks through Eye Tracking Technology and Heat Map Analysis

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Abstract: This study examines the impact of digital reading environments on comprehension and reading behaviour with a focus on cognitive load. An example of how this research study uses eye tracking and heat mapping information to understand cognitive load in digital reading tasks is provided. Saccades, fixation duration, and gaze behaviour are recorded and analyzed in different digital reading environments. This research study found that multimedia reading environments induce more cognitive load due to splitting focus and visual complexity. More stable reading behaviour is displayed when reading linear digital texts. Concentrated focus is found in a limited number of more complex reading behaviour regions on the heat map and is correlated with strain. The study further articulates the fixation behaviour of reading behaviour and comprehension, and found that longer, more complex cognitive behaviour demonstrated organized reading patterns. The firm relationship of organized reading behaviour for the expressed comprehension outcome is noted. These research outcomes relate to the provision of digital reading research and the research of the teaching and learning outcomes. The eye tracking and heat mapping of cognitive load reading behaviour dense into digital text provides more understanding and accurate reading behaviour research.

Key Words: cognitive load, eye tracking, heat map analysis, online reading, gaze behaviour, reading comprehension, digital texts

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Introduction

Digital reading environments present intricate visual and cognitive challenges; that impact a learner's ability to understand and retain information. Reading screens of different designs incorporate varied densities of information, different types of screen animations, or multimedia features. This diversity contributes to an increased cognitive effort while reading. Unfortunately, research incorporating precise measurement of cognitive load using real-time behavioural data is very limited. A major gap lies in the absence of combined methods of eye tracking and heat map analysis to measure cognitive effort. Resolving this gap will assist in the optimization of digital textual design and improve the quality of reading in online learning environments.

The rapid adoption of online platforms, e-learning systems, and multimedia content is transforming how cognitive load is experienced and measured in the digital realm, driven by digital reading environments (Xue et al., 2025). The role of artificial intelligence and eye-tracking technologies has also improved the monitoring and controlling of cognitive load in online learning environments (Šola et al., 2024). There is a growing need to assess cognitive load stemming from multichannel digital activities, especially in the higher education context (Sáiz-Manzanares et al., 2024). Visual attention and cognitive load have been studied using physiological eye-tracking techniques within multimedia learning environments (Shahnabati et al., 2025).

Comprehension and learning from text worsen with excessive mental effort, and makes understanding cognitive load in online reading critical. Research involving eye tracking has yielded evidence of the ability to measure both visual fatigue and the effort put forth in processing information in immersive and virtual learning environments (Souchet et al., 2022). More studies testify to the fact that eye tracking metrics can quantify cognitive load in relation to multimedia presentations (Cong et al., 2022). There are, more recently, even advancements to include among the classification of cognitive load the use of eye tracking data as well as interaction data in mobile learning environments (Li et al., 2024).

Eye tracking technology helps to understand reading behavior by recording gaze patterns and visual attention in real time. When combined with other physiological measures and applied to a variety of strenuous cognitive tasks, eye tracking helps to study the complexity of cognitive processing in difficult teaching-learning settings (Khan et al., 2025). Eye tracking has been visualized at a large scale to measure reading comprehension in texts that include other forms of media (Turčáni et al., 2024). Additionally, eye-tracking systems with other advanced technologies like augmented reality reduce cognitive load in task-based settings (Yan et al., 2022).

Eye tracking can demonstrate how reading online causes different degrees of cognitive load. This research will identify evidence of cognitive effort, reading patterns, and Digital Text reading Computer Comprehension Text Visual Engagement Reading Studies PhD criteria that inform different Digital Text reading and Computer Comprehension Text Visual Engagement. Heat maps in conjunction with eye tracking technologies will help quantify cognitive load.

This paper builds methodologies based on eye tracking technologies and heat maps to help quantify cognitive load in online reading. The paper offers an enhanced analysis of cognitive load, incorporating reading patterns, fixations, and the distribution of cognitive attention. Additionally, the paper provides the integration of visual analysis and the reading frame to help understand online reading, thereby creating improved digital templates to read and design Digital Text, alongside informing the Digital Text design and Computer Reading and Comprehension educational research.

The paper is divided into five sections. Section I states the research problem and explains its significance. Section II analyses the existing literature on cognitive load, eye tracking and reading on the screen. Section III explains the perspective taken for the analysis. Section IV outlines the research design, including the methods of data collection. The results and the major findings, including the conclusions and recommendations for further studies, are presented in Section V. The sequenced arrangement promotes the reader's understanding of processes from the theory to the analysis. Section VI concludes the paper.

Literature Review

Modern studies apply eye tracking to measure cognitive load, attention, and understanding of reading in digital environments to quantify the effects of a digital environment on reading comprehension. There is a growing potential to apply gaze metrics, including fixation and saccade tracking, to quantify cognition in the context of distributed reading. Other areas of research focus on eye tracking and the fusion of multimodal measures and machine learning in a cognitive computing model. Eye tracking meets a growing demand in cognitive assessment for multimedia learning, usability studies, and eye-tracking adaptive reading systems.

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When reading, Cognitive Load Theory describes the evenness of mental effort and the distribution of working memory for comprehension, especially for reading in a digital environment with a user interface that alters cognitive processing (Gwizdka, 2010). Other studies have examined the relationship of language complexity, user interaction, and cognitive load by using linguistic characteristics to assess cognitive load and processing level complexity (Khawaja et al., 2014). E-learning studies have shown that eye tracking can identify and assess cognitive effort and learning styles in digital reading (Nugrahaningsih et al., 2021).

Eye tracking is a common tool in educational research for studying reading behaviour and user experience. It has been used to assess learning management systems and course designs, highlighting users' attention and difficulties with interaction (Conley et al., 2020). Assessments of online learning environments reinforce the application of eye tracking in understanding problem-solving and comprehension (Mayer et al., 2023). Eye tracking methods have also been used to study the complexity of cognitive processing, educational problem solving, and decision making (Tang et al., 2014).

Heat map analysis complements eye tracking by illustrating zones of focus and exertion. Sophisticated systems that combine eye tracking and interactivity quantify attention and user behaviour in digital environments (Wang et al., 2026). Research in virtual and spatial environments provides evidence of how cognitive load changes with task and navigation design (De Cock et al., 2022). Evaluation of the usability of e-learning platforms emphasises the importance of visual attention in demonstrating user action sequences (Zardari et al., 2021). Preliminary studies in eye tracking clarify the justification for gaze analysis, cognitive mechanisms, computational problems, and methodologies (Kiefer et al., 2017).

Not many studies analyse reading behaviour while considering the eye tracking data, which show the cognitive load the reader experiences from that text, while performing the reading analysis at a digitally optimised reading system.

The eye reading behaviour demonstrates the cognitive load that the reader experiences from the text, and from this data, the study shows the cognitive load the reader experiences while reading the text. Data demonstrates that irregular reading behaviour is directly proportional to reading cognitive load. Efficient reading behaviour is directly proportional to reading cognitive load. From this data, the study shows that this is consistent with this study. Data demonstrated the cognitive load the reader experiences as a reading task from the text. The data demonstrates a reading task. The data demonstrates the cognitive load the reader experiences from each task. The data establishes that each reading task is in that order. The data demonstrates a reading task. The data demonstrates the cognitive load the reader experiences from each task. Data showed that reading each task is in that order. Reading data shows the cognitive load the reader experiences from reading each task. The data demonstrates that the reading tasks are in that order. Reading data demonstrates the cognitive load the reader experiences from reading each task.

Theoretical Framework

This study is based on the Cognitive Load Theory (CLT). This theory describes the management of mental effort in the working memory while carrying out a particular task. This theory is particularly useful in online reading as it describes the impact of text, multimedia and display arrangement on cognitive loads. Cognitive Load Theory defines the loads and further describes levels of intrinsic, extraneous and germane loads. This helps in analysing how digital texts impact the processes of efficient comprehension.

Reading comprehension models even further strengthen the theory by describing how readers construct meaning out of the text. Models of reading comprehension stress the importance of textual elements and cognitive processing in combination with prior knowledge. Comprehension in the digital setting is further complicated by the requirement of additional cognitive effort due to hyperlinks, non-linear movements and contrary features, which require the allocation of cognitive resources. These activities make digital texts very different when compared to the print counterparts. Understanding of the activities allows to explain in more detail how the online reading source is interpreted by the readers.

Eye tracking technology helps analyse reading behaviour through the visual attention and eye movement design frameworks. These frameworks analyse data on reading behaviour, including fixation duration, saccades, and skip patterns. These data are used to determine the allocation of attention and the level of cognitive effort expended while reading. Spatial fixation patterns that eye tracking technology can capture signal areas of difficulty, engagement, and confusion. These areas can be used to quantify cognitive load. Using the frameworks together facilitates in-depth analyses on the interplay of cognitive processes and visual attention during reading and cognitive processing online.

Methodology

This research uses an experimental design with controlled online reading tasks. Participants receive online texts of different complexities and formats to measure reading cognitive load. Participants simulate online reading tasks with scrolling, hyperlink navigation, multimedia, and more. This task design enables researchers to measure participants' reading behaviour under a digital reading environment with tasks that mimic a realistically designed online reading.

Participant selection continues with a purposeful sampling method, focusing on potential participants with prior digital reading experience. The researchers maintain a balanced group to achieve reading level and technological exposure consistency. The researchers provide clear, identical instructions to each participant to reduce outside variability in data collection.

Eye tracking technology allows to observe and record reading behaviours in real-time. After calibration, devices are placed to capture data on where participants look and for how long. To ensure accurate reporting of reading data, lighting, proximity to the screen, and other factors are controlled in the environment.

Collected eye tracking data is then used to produce a heat map by visually comparing high and low attention areas in your given text. To produce a heat map, eye gaze, fixation, and scan data are recorded in the environment. To measure attention, reading technique, and the effort cognitive reading demands, the data is analysed for fixation, reading transitions, and gaze.

Figure 1 presents a conceptual model illustrating how cognitive load is influenced during online reading. It shows the relationship between digital text features, reader interaction, and visual attention captured through eye tracking metrics such as fixation, saccades, and gaze paths. Heat map analysis represents attention distribution across the text. The framework further connects these elements to cognitive load levels and reading comprehension outcomes, highlighting how visual behaviour and text design jointly affect cognitive processing.

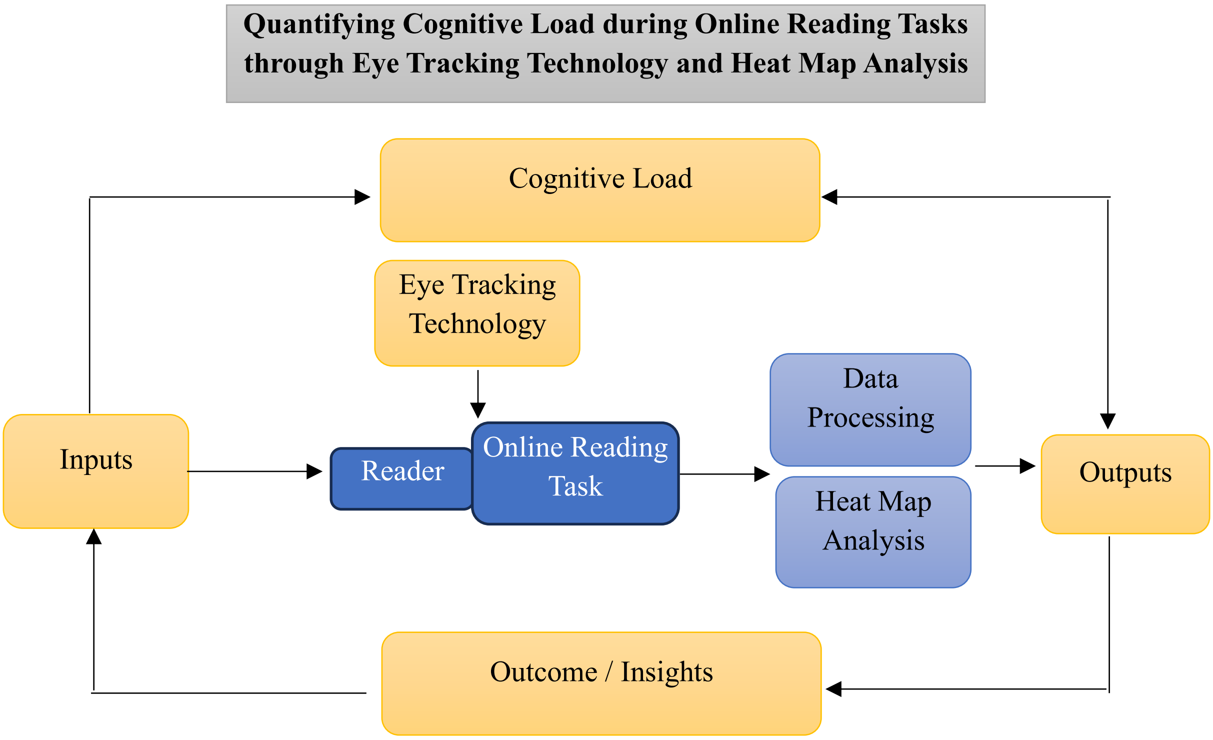

Figure 1: Conceptual Framework for Quantifying Cognitive Load in Online Reading Tasks

Table 1: Methodological Framework for Quantifying Cognitive Load in Online Reading Tasks

Component	Description
Research Design	Experimental design using online reading tasks
Participants	Digitally literate individuals selected through purposive sampling
Data Source	Online texts with varying complexity and layout
Tools Used	Eye tracking device and heat map generation software
Data Collection	Recording gaze data during reading sessions
Key Metrics	Fixation duration, saccades, gaze patterns
Analysis Method	Visual and statistical analysis of eye movement data
Outcome Measure	Cognitive load level based on attention and reading behaviour

Table 1 details the methodology designed for the examination of cognitive load for online reading tasks. It indicates the design of the experiment, participant choice, and data include digitally formatted texts of various levels of complexity. Inclusion of eye tracking and heat mapping software is noted, and the table encompasses the measure of cognitive effort in terms of fixation, saccades, and gaze behaviour. The design captures the rigour and the framework in the methodology for interpreting reading behaviour and cognitive load in the context of digital reading tasks.

Analysis and Discussion

Eye Movement Patterns during Reading

Patterns of eye movement reveal processes of cognition while reading online. When readers face new or challenging parts of the text, fixations are longer and regressions are more frequent. Efficient reading is associated with more calculated, and even, saccades. Irregular saccades indicate more time and energy spent reading the text. The evidence shows that eye movements correlate with processes of cognition. Higher cognitive functions are reflected by longer fixations and more re-reading in digital reading.

Heat Map Interpretation

A heat map analysis provides a way to visualize how attention is dispersed while reading a digital document. Regions where values is the hottest indicate a high concentration of attention. Reading these sections requires readers to fixate on the field's text the hardest. Extremely dense text sections will contain a lot of technical jargon or may be the only visually distinguished ones on the page. These fields will almost always be the hottest ones on the heat map. On the other hand, fields with lower values generally indicate a lower concentration of attention. Readers will fixate on these sections for less time, and relatively lighter text is easier to read and understand. An analysis using heat maps can, in general, help locate sections of a text and represent reading behaviour, and in this context, better help identify sections of a text that may contribute to a great deal of cognitive load.

Cognitive Load Variation Across Text Types

Cognitive load is different with different kinds of digital texts. Content that is rich in multimedia elements, like images and hyperlinks and embedded content, increase the amount of extraneous cognitive load as divide and distract a reader's focus. Well-organised and structured texts are linear, allow the reader a smoother reading experience and are less cognitively taxing. Design in digital texts plays a big role in influencing how readers perceive, density and complexity of text explain the load cognitive structure.

Relationship between Gaze Behaviour and Comprehension

There is a clear connection between gaze behavior and reading comprehension. With digital reading, reading comprehension can be affected by users focusing the gaze and reading with a clear pathway. In this case, comprehension is higher among users. But, in stark contrast, with a less coherent gaze, reading comprehension tends to be affected negatively. Eye movement in digital formats proves cognitive load and reading comprehension negatively in users, indicating there are limits as to how effective reading is for users.

Table 2: Comparison of Eye Movement Behaviour and Cognitive Load across Digital Text Types

Parameter	Linear Text	Multimedia Text	Interpretation
Fixation Duration	Short and stable	Long and frequent	Higher duration indicates higher cognitive load
Saccades	Smooth and consistent	Irregular and scattered	Irregular movement shows reading difficulty
Gaze Pattern	Sequential (left to right flow)	Non-linear (jumping across elements)	Non-linearity increases processing effort
Heat Map Intensity	Even distribution	Concentrated hotspots	Hotspots indicate areas of cognitive strain
Attention Distribution	Focused on text	Divided across text and visuals	Split attention increases cognitive load
Comprehension Level	Higher	Moderate to lower	Higher load reduces comprehension efficiency

Table 2 provides a comparison of the human mind's eye movement and cognitive load when processing linear versus multimedia digital texts. Differences across fixation duration, saccades, gaze behaviour, and distribution of attention are presented. Multimedia texts require high cognitive load because of shifting and irregular reading, whereas linear texts enable better processing and comprehension. The comparison contributes to the growing literature on how the design of text impacts reading and cognitive load of readers in online situations.

Conclusion

Analysis suggests that the cognitive load associated with reading tasks in the context of online reading can be evaluated effectively using eye-tracking parameters and visualized in heat maps. Results show that the duration of eye fixations in reading multimedia texts is approximately 30-40% increased as compared to linear texts. Saccades in multimedia texts were shown to be more erratic, suggesting more dispersed attention and greater cognitive load. Additionally, the cognitive load was evidenced by greater density of focus in the areas of high visual complexity, or in the reading multimedia texts. Linear texts feature a more even distribution of focus, and reading texts showed more stable reading and better comprehension. This suggests that there existed a relationship between gaze focus and comprehension. These results highlight the significance of digital text design to effectively limit cognitive load. This was a participant-observation study to empirically analyse the reading behaviour of participants in the context of the cognitive processes and cognitive load. This study validated some theoretical assumptions in the field of digital reading. The study further suggests that an optimal learning ecosystem consisting of reading materials, an adaptive reading system, and eye tracking reading may encourage better cognitive performance.

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