

Multidisciplinary Reading Patterns of Digital Documents

Bhanuka Mahanama
Gavindya Jayawardena
bhanuka@cs.odu.edu
gavindya@cs.odu.edu

Department of Computer Science
Old Dominion University
Norfolk, VA, USA

Yasasi Abeysinghe
Vikas Ashok
yasasi@cs.odu.edu
vganjigu@odu.edu

Department of Computer Science
Old Dominion University
Norfolk, VA, USA

Sampath Jayarathna
sampath@cs.odu.edu
Department of Computer Science
Old Dominion University
Norfolk, VA, USA

ABSTRACT

Reading plays a vital role in updating the researchers on recent developments in the field, including but not limited to solutions to various problems and collaborative studies between disciplines. Prior studies identify reading patterns to vary depending on the level of expertise of the researcher on the content of the document. We present a pilot study of eye-tracking measures during a reading task with participants across different areas of expertise with the intention of characterizing the reading patterns using both eye movement and pupillary information.

KEYWORDS

Eye Tracking, Reading Patterns, Multidisciplinary Research

ACM Reference Format:

Bhanuka Mahanama, Gavindya Jayawardena, Yasasi Abeysinghe, Vikas Ashok, and Sampath Jayarathna. 2022. Multidisciplinary Reading Patterns of Digital Documents. In *2022 Symposium on Eye Tracking Research and Applications (ETRA '22)*, June 8–11, 2022, Seattle, WA, USA. ACM, New York, NY, USA, 2 pages. <https://doi.org/10.1145/3517031.3531630>

1 INTRODUCTION

The reading patterns of digital documents (scholarly articles) vary from person to person across various disciplines. Despite the consensus that reading patterns are stochastic, recent studies identify similarities between individuals with common expertise. The studies by [Jayawardena et al. 2020; Mahanama et al. 2021] identify that participants spend the most time in the methodology section, with a relatively low cognitive load.

However, these studies only rely on pilot studies of participants from the computer science domain. As a result, the findings of the studies can be questionable for other disciplines. Therefore, we present a dataset¹ that includes eye-tracking behaviors of researchers from multiple disciplines. The contributions of our study are as follows,

- (1) Conduct a preliminary analysis on the generalizability of claims of previous studies across domains.

¹<https://github.com/nirdslab/Multidisciplinary-Reading-Patterns>

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
ETRA '22, June 8–11, 2022, Seattle, WA, USA
© 2022 Copyright held by the owner/author(s).
ACM ISBN 978-1-4503-9252-5/22/06.
<https://doi.org/10.1145/3517031.3531630>

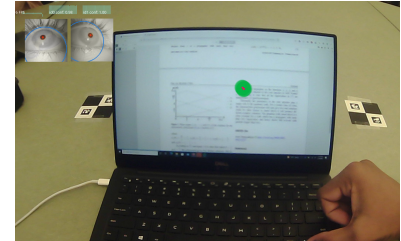


Figure 1: Experimental setup. Left: Participant during reading task, Right: Sample recording.

- (2) Discuss the potential usage of our dataset and findings towards digital documents and applications.

2 METHODOLOGY

We recruited seven (6 F, 1 M) graduate students as researchers in Computer Science (CS) (2), Mathematics (2), and Physics (3). The research experiences of the participants ranged between one year to five years and aged between 25 - 35 years. We confirmed their experience in reading research papers in conference venues verbally. We verified the vision of the participants through a visual acuity test.

We selected two articles of two pages in Computer Science and Physics for the reading task. After reading each paper, each participant briefly summarized the article verbally and answered queries by the proctor to confirm their understanding. We allowed the participants to perform the task in a laboratory setting with their preferred lighting, brightness, and zooming levels (See Figure 1 for the experimental setup). On a given day, we limited the experiment to a single paper per participant to eliminate the effects of fatigue in the dataset.

We used PupilLabs Core² eye-tracker to record eye-movements at a sampling frequency of 120 Hz with an accuracy of 0.60°. Each participant was calibrated using the 5-point calibration in Pupil Capture³ and confirmed the accuracy through manual tests. For each paper, we annotated five sections: (1) title, (2) abstract, (3) introduction and related work, (4) methodology, and (5) figures. We contacted the author and confirmed the section classification for the articles without explicitly defined sections.

For each user session, we replayed the gaze positions using Pupil Player and annotated the eye movements in each of the

²<https://pupil-labs.com/products/core/>

³<https://docs.pupil-labs.com/core/software/pupil-capture/>

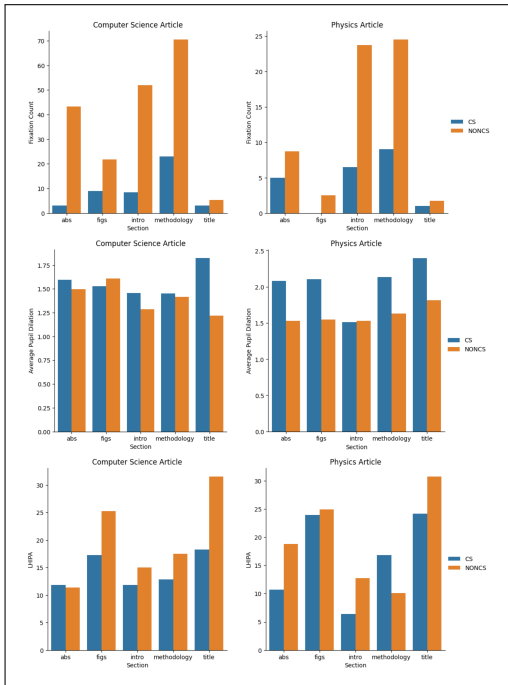


Figure 2: Top: Average Fixation Count, Center: Average Pupil Dilation, Bottom: LHIPA.

sections with a forum of three manual annotators. Then we extracted the annotated data from Pupil Player software and utilized x , y , $timestamp$, and $pupil\ diameter$ within each section to generate multiple eye gaze metrics. Based on the annotations, we computed fixation count, fixation duration, Low/High Index of Pupillary Activity (LHIPA) [Duchowski et al. 2020], and average pupil diameter. We calculated the aforementioned eye gaze metrics for each participant, for each paper, for each section including revisits to the same section.

3 RESULTS

Our preliminary results indicate the participants fixated more on the methodology sections of the paper irrespective of the domain consistent with the past studies [Jayawardena et al. 2020; Mahanama et al. 2021]. Considering the computer science article, Non-CS participants have more fixation counts across all sections than CS participants. We suspect familiarity with the content as a possible reason for the behavior. Moreover, we observe similar behavior (fixation count ranking) among Non-CS participants while reading the physics article, with much lesser fixations.

Following the behavior of Non-CS participants, we expected CS participants to exhibit a higher number of fixations while reading the physics article. On the contrary, we observed the number of fixations decrease while being lesser than Non-CS, indicating less time spent. We presume the CS participants have only skimmed through the content combined with the unfamiliar content.

While reading the physics article, we observed that CS participants have comparatively larger pupil dilation than Non-CS participants, potentially indicating domain unfamiliarity increasing

their cognitive load. However, we did not notice much difference between participants while reading the computer science article.

While reading the physics article, CS participants have experienced a higher cognitive load (lower average LHIPA) with the highest during the introduction. In contrast, Non-CS participants have experienced the highest in the methodology section with lesser cognitive load in other sections. In contrast, CS participants have undergone a higher cognitive load throughout the computer science article except abstract than Non-CS participants, despite our expectation of domain familiarity yielding a lower cognitive load.

4 DISCUSSION AND CONCLUSION

We did not observe domain familiarity impacting cognitive load expressed through pupillometric characteristics based on the results. However, we observed higher fixations in abstract, introduction, and methodology irrespective of the domain familiarity. Moreover, we noticed a higher cognitive load during introduction and methodology irrespective of participant and article.

Our preliminary results have multiple limitations. Firstly, we expect the observations to include potential biases resulting from the lack of diversity in our study sample due to the early stage of the study. We expect more generalizable gaze and pupillometric characteristics to emerge by diversifying the study participants. Further, we present only the most widely used measures in this study, while metrics beyond our study may uncover novel findings.

In the study, we performed manual annotations for mapping the gaze positions of the users to the sections of the paper, which is tedious and time-consuming for an experiment of large scale. As presented in prior studies [Jayawardena and Jayarathna 2021; Mahanama et al. 2021], automated annotation approaches can help overcome the issue and form a novel research avenue. However, our experimental setup requires a clear point of view imagery and distinctive features in the digital documents to use those approaches effectively. Further, such an automated approach must be resilient to potential false positives in categorization.

ACKNOWLEDGMENTS

This work is supported in part by the U.S. National Science Foundation grant CAREER IIS-2045523. Any opinions, findings and conclusion or recommendations expressed in this material are the author(s) and do not necessarily reflect those of the sponsors.

REFERENCES

- Andrew T Duchowski, Krzysztof Krejtz, Nina A Gehr, Tanya Bafna, and Per Bækgaard. 2020. The low/high index of pupillary activity. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–12.
- Gavindya Jayawardena and Sampath Jayarathna. 2021. Automated Filtering of Eye Movements Using Dynamic AOI in Multiple Granularity Levels. *International Journal of Multimedia Data Engineering and Management (IJMDEM)* 12, 1 (2021), 49–64.
- Gavindya Jayawardena, Sampath Jayarathna, and Jian Wu. 2020. Analyzing the effect of reading patterns using eye tracking measures. In *Proceedings of the ACM/IEEE Joint Conference on Digital Libraries in 2020*. Association for Computing Machinery, New York, NY, USA, 517–518. <https://doi.org/10.1145/3383583.3398591>
- Bhanuka Mahanama, Gavindya Jayawardena, and Sampath Jayarathna. 2021. Analyzing Unconstrained Reading Patterns of Digital Documents Using Eye Tracking. In *2021 ACM/IEEE Joint Conference on Digital Libraries (JCDL)*. IEEE, 282–283. <https://doi.org/10.1109/JCDL52503.2021.00036>