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Evaluating Human Eye Features for Objective Measure of Working Memory Capacity

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ABSTRACT

Eye tracking measures can provide means to understand the underlying development of human working memory. In this study, we propose to develop machine learning algorithms to find an objective relationship between human eye movements via oculomotor plant and their working memory capacity, which determines subjective cognitive load. Here we evaluate oculomotor plant features extracted from saccadic eye movements, traditional positional gaze metrics, and advanced eye metrics such as ambient/focal coefficient $\mathcal{K}$, gaze transition entropy, low/high index of pupillary activity (LHIPA), and real-time index of pupillary activity (RIPA). This paper outlines the proposed approach of evaluating eye movements for obtaining an objective measure of the working memory capacity and a study to investigate how working memory capacity is affected when reading AI-generated fake news.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

Cognitive Load, Eye Tracking, Misinformation

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1 INTRODUCTION

With the advances in large language models such as GPT-3 [Brown et al. 2020] and Megatron-Turin NLG [Smith et al. 2022], artificial intelligence systems are capable of synthetically generating misinformation, which is convincing enough to deceive experts in critical fields like medicine and defense [Ranade et al. 2021]. Wide use of these AI-generated texts and their capability to mimic human-created news aid the spreading of online misinformation. Studies assessing the credibility of AI-generated texts, and the influence of such texts, have shown that human perceptions of AI-generated text are relative to an original story [Kreps et al. 2022], and humans are largely incapable of distinguishing between AI- and human-generated text [Kreps et al. 2022; Ranade et al. 2021]. Understanding the variations in visual attention including the cognitive load of humans when consuming fake information can be useful in detecting misinformation in AI-generated texts.

The working memory capacity (WMC) of humans can be used as a measure to understand how the human working memory uses attention to hold and process new information. Understanding WMC has been challenging as there is currently no direct method of determining a person's WMC without distracting them from their tasks. Even though the complex span task and n-back task measures are commonly used to measure the WMC, they can only be measured by observing the way they affect peoples' information processing, learning, and memory. Eye movements, attention, and working memory are tightly linked together. The advancement of eye-tracking technology allows us to use eye movement measures for real-time monitoring of human subjects (eye movements) while performing a task and performing real-time implementation with a reduced computational cost.

The human oculomotor plant is represented by a mechanical model composed of six extraocular muscles attached to an eye globe. Oculomotor Plant Feature (OPF) values are the anatomical components of extraocular muscles which are responsible for eye movements. The oculomotor plant exhibits six eye movement types namely fixations, saccades, smooth pursuits, optokinetic reflex, vestibulo-oculor reflex, and vergence. Fixations (relative eye gaze position at one point on the stimuli) provide information about the memory state because the only way to acquire information visually is by placing the eye gaze position on the stimuli location. A saccade (rapid eye movements of gaze from one fixation point to another) itself is not an effective source of relevance as humans are effectively blind during a saccadic movement where the eye is in motion. However, fixations require proceeding saccades help to place the gaze on the stimuli to gather information from the target location. These eye movements can be analyzed to derive human attention patterns and to understand the underlying deployment of human working memory.

These eye movements along with pupillary information can be used to obtain traditional positional gaze metrics and advanced eye metrics such as ambient/focal attention with coefficient $\mathcal{K}$ [Krejtz et al. 2016], gaze transition entropy [Krejtz et al. 2015], low/high index of pupillary activity (LHIPA) [Duchowski et al. 2020], and real-time index of pupillary activity (RIPA) [Jayawardena et al. 2022]. These metrics have been widely used to assess human visual attention [Jayawardena et al. 2020; Krejtz et al. 2016, 2015, 2014]

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including cognitive load measures [Duchowski et al. 2020, 2018; Jayawardena et al. 2022; Krejtz et al. 2018]. Krejtz et al. [Krejtz et al. 2016] introduced coefficient $\mathcal{K}$ which is derived from eye movements and acts as a dynamic indicator of fluctuation between ambient/focal attention. The gaze transition entropy [Krejtz et al. 2015, 2014] is a measure of predictability in Areas of Interest (AOI) transitions and the overall distribution of attention over AOIs. The LHIPA [Duchowski et al. 2020] and RIPA [Jayawardena et al. 2022] are eye-tracked measures of pupil diameter oscillation that were introduced as indicators of cognitive load. These advanced eye metrics derived from eye movements can be used to explore to find relationships with WMC.

2 RESEARCH OBJECTIVE

We intend to develop a modeling framework using machine learning algorithms to use eye-tracking measurements for indexing WMC. We explore different human eye features such as OPF, traditional positional gaze metrics, and advanced eye metrics to find an objective relationship between participants' eye-tracking measurements and WMC measures. This paper outlines the proposed approach of evaluating the human eye features for obtaining an objective measure of the WMC. Furthermore, this paper outlines a study designed to investigate how human WMC is affected when reading AI-generated misinformation.

3 PROBLEM STATEMENT AND HYPOTHESES

Reading relies on the visual processing of text and individuals' eye movements reflect this ad-hoc visual and cognitive process. In the literature, there have been several studies that introduced different advanced eye metrics that can be used as indicators of visual process and cognitive load. We hypothesize that the characteristic movements of the human eye and metrics derived from eye movements may be utilized to find an objective relationship with human cognitive load measures. Identifying those parameters will allow us to build a model that is capable of providing an objective measure of WMC.

3.1 Research Questions

We will investigate the following research questions.

(1) Is there a relationship between eye movement metrics via oculomotor plant and WMC measures?
(2) Can traditional positional gaze metrics and advanced eye metrics be used in understanding objective measures of working memory?
(3) Can human eye measures use to build an oculomotor plant model that can index WMC?
(4) Can we use WMC to determine objective measures for identifying misinformation in AI-generated texts?

4 APPROACH AND METHODS

We will first preprocess the raw eye movement data and extract valid raw data as (x, y) coordinates, timestamps, and pupil diameters. We will then utilize Real-Time Advanced Eye Movements Analysis Pipeline (RAEMAP) [Duchowski 2017; Jayawardena 2020; Jayawardena et al. 2020] eye movement processing library to facilitate computation of traditional positional gaze metrics and advanced eye metrics. We will employ the existing methods [Shanmugathasan and Jayarathna 2018] to extract the OPF of the human eye during saccadic movement.

We will develop machine learning algorithms to identify human eye features such as OPF, traditional positional gaze metrics, and advanced eye metrics to predict the WMC. By building various machine learning models we expect to find the extent to which the psychological metrics representing the human eye feature set predict levels of WMC values. Thus we will design an oculomotor plant model that can be used as an objective measure of WMC.

We will conduct an experiment to acquire eye-tracking data from a fake news reading task. We will utilize openAI chatGPT tool to generate synthesized text on different topics which include fake news. To avoid the sequence effect, the topics were presented in random order per participant ensuring that both fake and real news items were presented the same number of times. The participants rate the credibility of the news content. We will utilize the modeling framework that will be designed in this study, to generate the WMC of participants while reading fake and real news. We will analyze how WMC values are affected when consuming fake news than real news.

5 PRELIMINARY RESULTS

We conducted a pilot study to analyze LHIPA, an eye-tracked measure of pupil diameter oscillation that is introduced as an indicator of cognitive load, in a fake news reading task. We observed that there is no significant difference between LHIPA scores with respect to truthfulness and human perception of the believability of the news content.

6 PLANS FOR FUTURE WORK

In future work, we plan to explore deep learning algorithms for identifying eye movement patterns that can be used in understanding objective measures of working memory. Upon building a modeling framework that can be used as an objective measure of WMC, we plan to conduct a comprehensive user study to determine how the cognitive load of humans varies when they are consuming fake news. Finally, we will evaluate the performance of the framework in different complex tasks.

7 BROADER IMPACT

The modeling framework will index the WMC of humans using their eye movements. We will contribute to the literature for a better understanding of how human eye features can be used as an objective measure for WMC. Further, it will also contribute to the literature by presenting how the WMC can be affected in the fake news reading task.

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