Towards Early Dementia Detection by Oculomotor Performance Analysis on Leisure Web Content

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Abstract
The oculomotor performance can be an indicator of early neurodegeneration. Persons with Alzheimer’s disease have shown different eye movement patterns than healthy persons in visual exploration through different experiments. We present a non-obtrusive approach for the assessment of oculomotor performance that can be useful to detect early stages of dementia. Our proposal uses a non-intrusive method to analyze how people explore leisure web content. In this paper, we discuss literature, our initial design, and the future directions of the project.

Author Keywords
Oculomotor performance; Eye movements; Alzheimer’ disease; Early diagnosis.

ACM Classification Keywords
H.5.m. Information interfaces and presentation.

Introduction
People with dementia (PwD) have different oculomotor performance when compared against healthy people [11]. For instance, PwD have slower responses to appearing visual targets [12], have more difficulties to

spot specific objects when observing pictures, [5,7] and show different reaction when novel objects are presented to them [2]. The decline of oculomotor performance is considered a subtle early manifestation of dementia and might correlate with dementia severity [1,11].

To analyze the decline of oculomotor performance, researchers use eye trackers, which are devices that gather eye movement data. Currently, there are commercially available screen-based and mobile eye trackers [16,17]. However, this technology is expensive and still requires a cumbersome calibration procedure [13].

Most studies on eye movements and dementia have been conducted under controlled laboratory settings. For example, the work in [12] uses a screen-based eye tracker to measure the reaction time when a target appears on a screen. Other work also uses a screen-based eye tracker device to measure subject's accuracy and reaction time when asked to identify a specific scene while looking at pictures containing different scenarios (e.g. natural vs urban, indoor vs outdoor) [5]. Although these works provide important insights regarding eye movements and dementia, they still have not analyzed eye movement on naturalistic settings, thus they may not be suitable for early detection. The research in [4] is oriented to analyze eye movements in a more common task: reading sentences. While researchers have identified significant differences between healthy subjects and PwD when reading sentences, the studies are limited to the use of fixed eye trackers and the control of head movements through a chinrest.

Studies on how healthy people and PwD react to novel and repeated stimuli have shown differences on their reactions that can be used to predict a transition from a healthy to a mild cognitive impairment status, and dementia before the diagnosis [2,3,9]. Currently, the commercial application Neurotrack™ uses a web camera for eye tracking and analyzes eye movements from subjects exploring images [18]. The process initiates with a calibration stage by asking users to locate their face on a specific region and to perform specific eye movements. After calibration, several slides with images are presented to the user while she or he maintain the posture. After a few slides, images previously presented are shown again. The application then analyzes the recorded users' eye movements during their visual exploration. The application computes a score of the neurological status of the subjects. It also reminds users to periodically take the test to track the oculomotor performance with the purpose of detecting neurological decline. The importance of this application relies on the use of a web cam-based eye tracker and the ability to take a test on any location. However, there is the need to have a pervasive method to assess oculomotor performance in naturalistic settings. The later is important for early detection, when there is still no notion about having early cognitive decline that can otherwise motivate people to take mental health tests.

We propose to analyze eye movement data while users are browsing leisure web content, such as Facebook, Twitter, or another social web content. These social network platforms have millions of daily users around the world who surf among their content through computers or mobile devices [15]. The rich visual content of these sites includes text, images, and video.

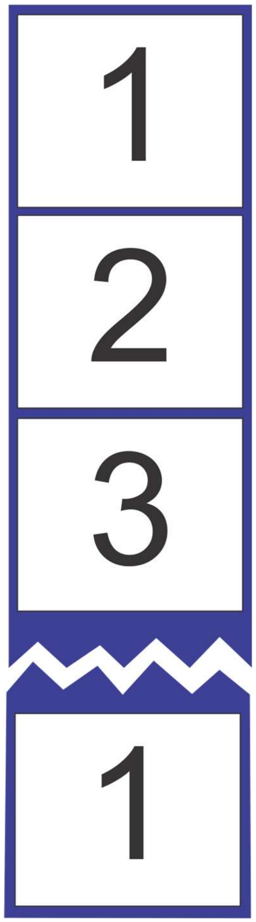

Figure 1. Illustration of the content feed strip. To explore novelty reaction, after several "posts" there is a repeated image.

Moreover, these sites allow user interaction through likes on posts, comments, and even responding to surveys. These features can be used to design ubiquitous tests suitable for dementia studies through oculomotor performance analysis. The wide use of social networks by young people serves as a medium in the research towards the detection of early stages of dementia in the following years.

Currently, our work is on an early stage. However, it has strong foundations and we believe its development promises a tool useful for assessing mental health problems. Next sections describe the platform design so far and our future directions.

Design

Camera and eye tracker

Our platform uses any web camera and is based on the eye tracker described in [6]. This eye tracker is self-calibrated by the user interaction with the web content through mouse clicks. When users are interacting with leisure content, they might be constantly changing posture and the calibration through mouse clicks is a suitable approach for noninvasive calibration. However, there is a data loss that might affect oculomotor performance analysis. The analysis with these data losses is a challenge that will be addressed in forthcoming stages of our work.

Visual content

The design of visual content to evaluate the oculomotor performance is arranged as a content feed strip (CFS) like the wall from Facebook (see Figure 1). Each *post* contains a figure or text designed to evaluate the oculomotor performance during its observation. For example, as shown in [3,9], spending more time viewing novel pictures compared to time spent on previously presented picture indicates intact memory. Taking this into consideration, the content from the CFS includes repeated images. The purpose is to evaluate the time that users spend and the eye movement patterns on those repeated images before scrolling to the next content. Figure 1 illustrates this scenario.

Other findings from literature suggest that processing or disengaging attention problems are evidenced by the PwD exhibiting longer fixation when searching in visual content compared with healthy persons [10]. Also, a lack on organized scan path during visual exploration, suggests a decline on the process of spatial attention [10]. To use these findings on the CFS, we include content to evaluate the exploration. For example, Figure 2 shows an image asking a user to identify differences between two images and Figure 3 asks to the user to identify the letter *2* among a field filled with letter *Z* and click on it. Moreover, by asking to the users to interact by clicking on buttons, we are fulfilling the self-calibration requirements by the webcam-based eye tracker.

Our initial studies do not include all current social networks features with the purpose of controlling variables that might interfere with attention. For example, a user from Texas might be interested and spend time on a news from Texas, while a user from Ontario might ignore that news but be interested in a news from Canada. In fact, the content to be displayed is designed based on literature about visual attention. However, further stages are intended to analyze eye movements in the exploration of these social networks.

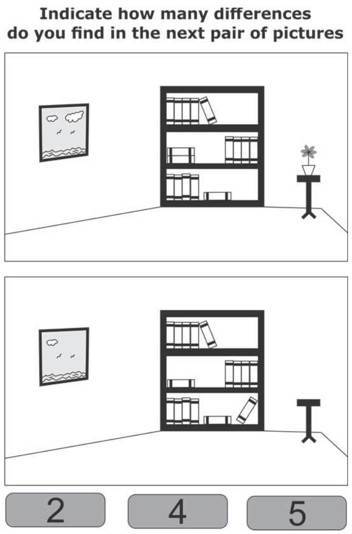

Figure 2. Instruction to click on the number of differences in two pictures as a strategy for calibration and analysis.

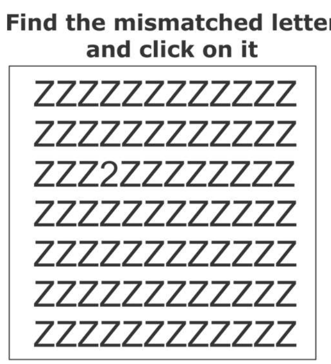

Figure 3. Instruction to click on a mismatched letter as a strategy for calibration and analysis.

Comparison of visual exploration patterns

To compare how users explore the visual content, the time spent on each region of the CFS plays an important role. With time, we can know for example, if a subject is ignoring repeated content or is having a hard time encountering the number 2 among the Zs.

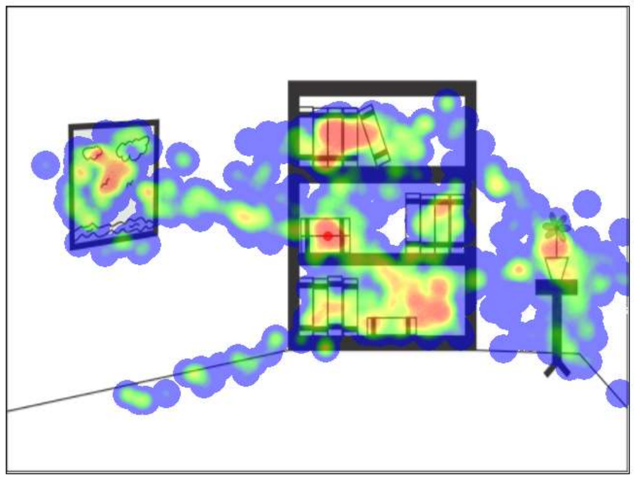

Figure 4. Example of a fixation map over a region from the CFS.

In addition, to compare the scan path followed by the subjects, we use a fixation map created from the eye tracker data. A fixation map is a three-dimensional image where the X and Y axes represent location and the Z axis indicates the amount of fixations in that location [14]. In the creation of the fixation map, a Gaussian is placed on every fixation point to generate a continuous distribution that represent the elements from the image receiving attention. To compare fixation maps there are different metrics that can be used, such as the Earth Moving Distance (EMD) that measure the distance between two probability distribution [8]. Figure 4 shows an example of a fixation map we generated from the eye movements over a region of the CFS. The red color indicates more fixations, blue color indicates less fixations and white regions had no fixations at all.

Discussion and Future directions

We present our research on a pervasive tool aimed for early detection of dementia. Our work is different from other research with established fixed scenarios. In the proposed approach, the user can interact with the visual content and move through a content feed strip at its own preference and pace. As future steps, we will experiment with different metrics to find a suitable comparison technique of eye movements on visual exploration for the detection of dementia. Along with these metrics, we will use machine learning algorithms to generate models of the eye movements patterns from PwD. Simultaneously, we are on a recruiting stage of participants with mild cognitive impairment. The future directions are the analysis of the oculomotor performance along with typical content from Facebook. Another direction consists in developing the pervasive tool on mobile phones. This later includes eye tracking challenges because of posture constraints, illumination, and changes on the strategies for self-calibration. However, mobile phone usage provides a rich source of information to be used for addressing early neurodegenerative diseases diagnosis.

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