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Editorial

From the Eyes to the Suffering Brain: Can Eye Tracking be Considered as a Significant Digital Biomarker for Neurological Diseases?

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Eye movements are a basilar aspect of vision and are supported by several neurological functions, including visual processing in the brain, the transmission of information through the optic nerve and coordination. According to some authors [1], when one of these functions is impaired by a disease or injury, how the eyes move can also be affected. During neurological examination, it is important to assess intentional and unintentional ocular movements to determine the integrity and proper functioning of the three pairs of skull nerves—the abducens, trochlear and oculomotor nerves—and investigate several circuits distributed throughout the central nervous system [2]. Considering the large number of circuits in the cerebral hemispheres, cerebellum and brainstem involved in gaze control, there is a strong indication that eye movement is impaired in a variety of neurological disorders characterised by neurodegenerative phenomena [3].

Several new technologies have emerged in the field of neuroscience as innovative tools offering valuable insights into the cognitive functions of the human brain. Eye-tracking is an experimental methodology for registering eye movements and gaze position over both time and tasks that is frequently used to investigate perception, attention, cognition and decision-making [4,5]. According to Augustine and colleagues [6], ocular movements may be categorised into two different classes of function: one consists of movements that serve to fix gaze, while the other includes movements used to change visual direction. Eye movements that fix gaze comprise vestibulo-ocular and optokinetic movements, while those that shift gaze direction include vergence movements, slow pursuit movements and saccades [6]. Current commercially available eye trackers have a sampling rate between 30 Hz and 2000 Hz; due to this significant difference, only a few are capable of recording all these types of eye movements [5]. Recent studies have reported how eye-tracking can be combined with other techniques, such as functional magnetic resonance imaging or electroencephalography, to gain a deeper understanding of the correlation between eye movements and cortical activity in a complex pattern of behaviour [7,8].

Neurological disorders can be characterised by an impairment of ocular motor function, which could manifest as various abnormalities of saccadic, pursuit and fixation movements. Researchers can measure these eye movements accurately with the use of high-resolution eye trackers to detect those subtle alterations associated with specific neurodegenerative conditions that could facilitate a differential diagnosis. For example, some authors [9] have detected how patients with Parkinson's disease may show slight alterations in slow pursuit movements, as well as a reduction in the gain of voluntary saccades, whereas patients with Huntington's disease can have difficulty generating a saccade in reaction to a verbal command, performing this movement with increased latency and more slowly, particularly along the vertical direction [2]. Patients with spinocerebellar ataxia may present with a range of alterations during intentional ocular movements due to degraded cerebellar circuits, which can contribute to the regulation of the brainstem circuit gain responsible for the control of conjugate movements, including the vestibulo-ocular reflex [2,10]. In addition, patients with frontotemporal dementia or Alzheimer's disease typically make more errors when engaged in anti-saccadic or saccadic suppression tasks, showing gaze instability and increased latency of both voluntary and reflex saccades [2,11]. The presence of eye-movement disorders in patients with neurological diseases suggests that the aetiology may directly affect the central circuits that control the orientation and stabilisation of gaze, but it may also be possible that alterations in visual behaviour can aggravate functional decline by impairing the cognitive and perceptual performance experience of the surrounding environment [6]. Moreover, researchers using eye-tracking paradigms have shown that there is a progressive deterioration in oculomotor function over time, which correlates with cognitive decline and neuroimaging findings [8,12]. In either case, the clinical assessment of voluntary and involuntary eye movements via eye tracking could hold promise for providing digital biomarkers for disease severity, progression, and treatment response [13].

The present and near future of this field lies in harnessing the power of artificial intelligence. Training machine-learning algorithms has enabled the development of predictive models based on eye-tracking data, offering potential biomarkers for disease diagnosis and prognosis [14]. By analysing subtle changes in eye-movement patterns, researchers can discern disease-specific characteristics indicative of the underlying neuropathology. Despite the incredible potential of eye tracking, we still face several challenges before this method can be widely adopted in clinical routine: for example, the standardisation of protocols, validation of metrics and development of user-friendly interfaces will be necessary to ensure reliability and reproducibility in different contexts. Furthermore, adequate instrumentation in terms of power is mandatory to capture the different nuances of and subtle alterations in patients' eye-movement patterns. Finally, further ethical exploration will be needed, as problems with the collection and storage of biometric data must be addressed.

In conclusion, eye tracking represents a promising tool for producing reliable digital biomarkers for both clinical and research purposes, as it aims to facilitate the early diagnosis of neurological disorders, and, as technology advances, it will become increasingly affordable. The invitation we would like to extend with this editorial is to foster the improvement of the early detection of patients' conditions through innovative and less-invasive tools that allow for easier and safer monitoring of the disease over time. Eye tracking lends itself well to this purpose, but further methodologically robust research will need to be performed, and more scientific evidence will need to be systematically collected before it can be integrated into standard clinical practice.

Author Contributions

SC, UR and MC: Conceptualization, Writing, Original draft. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

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Conflict of Interest

The authors declare no conflict of interest. Marco Cavallo is serving as one of the Editorial Board members and Guest editors of this journal. We declare that Marco Cavallo had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Gernot Riedel.

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