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Eye-tracking for investigation of different functions of the nervous system in healthy students and patients with neurological conditions

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ABSTRACT

Eye-tracking can be used as a tool for investigating various functions of the nervous system for gaining data about cognitive processes, attention, perception, and control. Eye-tracking is a part of our projects for healthy students and patients with neurological conditions in Ufa, Russia.

Keywords: Eye-tracking, education, nervous diseases

INTRODUCTION

Eye-tracking can indeed be used as a tool for investigating various functions of the nervous system. By tracking the movements of the eyes, researchers can gain insights into cognitive processes, attention, perception, and control.

Eye-tracking technology allows for the measurement of eye movements, such as fixations (when the eyes are stationary) and saccades (rapid eye movements between fixations). This data can be analyzed to understand how the brain processes visual information, how attention is allocated, and even to assess neurological conditions. Eye-tracking studies have been conducted in various fields, including psychology, neuroscience, human-computer interaction, and clinical research.

PURPOSE OF THE RESEARCH

To do a literature review of using eye-tracking as a method for being used in education and in neurology, to illustrate the review with our data and examples.

MATERIAL AND METHODS

PubMed search using the key words «eye-tracking», «education», «neurology», and the results of our pilot project investigating healthy students using an eye-track-

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er (model «Scientific Edition») at Bashkir State Medical University in the framework of «Priority 2030» program.

RESULTS

For understanding Eye Tracking we analyzed the modern papers and learnt that eye tracking involves capturing eye movements, gaze points, and fixations to study visual attention and behavior. It provides data on where and how long a person looks at specific stimuli. [1]

Applications in Neuroscience and Nervous System Studies is based on the following: Eye tracking plays a crucial role in neuroscience to study various aspects of the nervous system: Cognitive Processes: Understanding how the brain processes visual information during decision-making, problem-solving, and other cognitive tasks [2]. Visual Perception: Investigating how the brain interprets and makes sense of the visual world. In neurological disorders eye-tracking can help detecting and assessing neurological conditions such as Alzheimer's, autism, Attention deficit and hyperactivity disorder, and Parkinson's by analyzing atypical eye movement patterns.

Putting together the information from the papers we present a brief overview of eye tracking and its relevance in studying the nervous system.

Eye Movement Patterns: Eye tracking helps analyze the patterns of eye movements during various tasks, which can reveal how the brain processes information and directs attention. For instance, studying saccades (rapid eye movements) and fixations (pauses) can shed light on cognitive processing and decision-making. [1]

Visual Attention and Perception: Eye tracking helps researchers understand how the brain prioritizes and allocates attention to different stimuli. This information is crucial for studying perception, visual memory, and how individuals interpret their environment.

Eye Movements and Cognitive Processes: we've learnt that Attention and Eye Movements are closely linked to each other. When we pay attention to something, our eyes typically fixate on it. Rapid eye movements, called saccades, occur between fixations to bring new objects of interest into the center of our vision. [2]

Perception and Eye Movements: Eye movements help construct our perception of the world. Our eyes move to gather detailed information about objects or scenes, and this information is then used to construct a coherent perceptual experience. [3]

Decision-making and Eye Movements is important to understand for different purposes, including educational activity for healthy students. Eye movements can reflect our decision-making processes. For instance, during a choice task, we might spend more time fixating on options we are considering, indicating the decision-making dynamics at play. [2]

By analyzing eye movements, researchers can gain insights into the cognitive processes involved in attention, perception, and decision-making. These processes are fundamental to how we interact with the world around us and are crucial for understanding various cognitive functions and disorders.

Eye-tracking Methodologies: Eye-tracking methodologies encompass various techniques and technologies that enable the tracking and analysis of eye movements. Two prominent types are the following: Video-Based Eye-Tracking and Infrared Eye-Tracking

Video-based systems use cameras to record and track eye movements by capturing images of the eyes. Advanced computer algorithms analyze the recorded video to determine the gaze point and movements. [3]

Infrared systems use infrared light to illuminate the eyes, making it easier to detect and track eye movements. The reflections of this light off the eyes are captured and analyzed to determine gaze points. [5]

Combined Methods are even more efficient. Some eye-tracking systems use a combination of video-based and infrared technologies to enhance accuracy and capture a wider range of eye movement data.

Portable Eye-Tracking Devices exist. Recent advancements have led to the development of portable and wearable eye-tracking devices, enabling research in real-world settings and scenarios. [3] [5]

There are also Remote Eye Tracking approaches. Remote eye-tracking systems use cameras to track eye movements from a distance without physical contact with the subject, providing a non-intrusive data collection method.

These diverse eye-tracking technologies and methodologies facilitate in-depth research into cognitive processes, visual attention, and various applications across psychology, neuroscience, human-computer interaction, and more.

We invited 10 healthy students from Ufa, Russia to participate in our pilot project. All of them gave their informed consent and agreed to be the subjects of this study. The age of the participants ranged from 18 to 25 years (mean 20.7 years, standard deviation 1.8). We used Stroop test which is described in [9] as following: «The Stroop Task is one of the best known psychological experiments named after John Ridley Stroop. The Stroop phenomenon demonstrates that it is difficult to name the

ink color of a color word if there is a mismatch between ink color and word. For example, the word GREEN printed in red ink. Colin MacLeod's (1991) review article in the influential psychological journal Psychological Bulletin is frequently cited when discussing the effect. There are many variations on the basic effect using other stimuli than colored words.» The number of words meaning colors in the test we used was 18.

We measured the time that each student needed for doing this test and the number of wrong answers. The time ranged from 17 to 41 seconds (mean 26.9 seconds, standard deviation – 7.6 seconds). Two students made 2 mistakes naming the color, one student made 1 mistake, but the majority (7 out of 10) named all the colors correctly. We'll extend the number of students-participants and will make a table of reference data, comparing the data we obtained with the data published in scientific journals in Russia and international ones.

We compared theses results with the results of patients with neurological conditions and found statistically significant difference.

We plan to use eye-tracking in combination with clinical tests for assessment of cognition, attention, speed of reaction and other parameters for mathematical analyses, modeling, and making proposals for optimizing the trajectory of education and recommending individual approach for study at the university for each student. Our design of this study includes making unique software and application for being used by students and their educators on their smartphones. We have a team of 20 people working at the moment for this project, including professors of neurology, psychology, mathematics and engineering; students and PhD students. We are supported by «Priority 2020» program at Bashkir State Medical University.

DISCUSSION

Eye-tracking technology has found substantial clinical applications in assessing neurological conditions, monitoring disease progression, and formulating rehabilitation strategies. It can also be used for healthy students in terms of assessment of their cognitive state and ability to study. In assessing neurological conditions, eye-tracking helps evaluate oculomotor function, gaze stability, and visual attention, providing valuable insights into disorders such as Parkinson's disease, multiple sclerosis, and traumatic brain injury. Additionally, monitoring disease progression is facilitated by tracking changes in eye movement patterns and gaze behavior over time, offering objective measures to track the evolution of neurological disorders.[6]

Furthermore, eye-tracking contributes to the development of tailored rehabilitation strategies by assessing visual impairments and aiding in the design of interventions to enhance gaze control, reading abilities, and overall quality of life for individuals with neurological conditions. [6, 7]

CONCLUSION

Eye-tracking has proven to be a crucial technology in advancing our understanding of the nervous system both in healthy individuals and in patients with neurological conditions. Through comprehensive research and clinical applications, it has provided invaluable insights into neurological conditions, disease progression monitoring, and rehabilitation strategies. By studying eye movements and gaze behaviors, researchers can assess oculomotor function, visual attention, and other aspects related to the nervous system's performance. [7, 8]

This technology has shed light on conditions such as Parkinson's disease, multiple sclerosis, and traumatic brain injury, enabling early detection, accurate diagnosis, and personalized rehabilitation plans. With PubMed resources, a wealth of scientific evidence supports the pivotal role of eye-tracking in neuroscience, ultimately contributing to improved patient care and outcomes [8].

The potential results of the research project that we plan can also contribute to making the knowledge in this field more precise and for optimizing care both for healthy individuals (students) and patients who undergo rehabilitation for neurological problems.

ETHICAL CONSIDERATIONS

Informed consent was obtained from all participants before they were examined using eye-tracking in this pilot project. No conflict of interest is declared. We did not use any financial support for this study yet. The research described here is a component of the frame All-Russia program «Priority 2030», and eye-tracker at Bashkir State Medical University that we used was purchased using the financial support from the above mentioned program «Priority 2030».

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