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STUDY OF PREFRONTAL OXYGENATION DURING EMOTIONAL THINKING USING FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (FNIRS)

Zaharaa Mohammed Kazem[*1], Ayat Hamid Taleb[2], Murtdha falah Abd Al-Hassan[3], Muqtada hussam Hussein[4], Noor hassan Naji[5], Tuqa Ihsan Abd Ali[6], Mahir Rahman[7]

[1,2,3,4,5,6,7] Department Graduation Project, College Biomedical Engineering, Al-Mustaqbal University

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Abstract: Introduction: This section provides an overview of the project and introduces the topic. It should include the background, objectives, and scope of the research. Literature Review: This section reviews relevant literature related to the topic to provide a better understanding of the existing research and technology available. It should include sources such as books, academic journals, and online articles. Methodology: This section outlines the methodology used to design and develop the project, including the hardware and software components, programming languages and tools used, and testing procedures. System Design: This section describes the architecture and design of the system, including the hardware and software components, communication protocols, and interfaces. It should provide a detailed explanation of how the system is structured. Implementation: This section details the process of implementing the system, including the setup of the hardware and software components, programming of the microcontroller and sensors, and integration of any external platforms.

Results and Evaluation: This section presents the results of the testing and evaluation of the system, including the performance, efficiency, and effectiveness of the system in achieving its objectives. It should also discuss any limitations or challenges encountered during testing. Conclusion and Future Work: This section summarizes the research findings and provides recommendations for future work. It should discuss any potential for further development and improvement of the system.

Keywords: Oxygenation, emotional, functional near-infrared spectroscopy, fNIRS.

INTRODUCION

Functional near-infrared spectroscopy (fNIRS) is a non-invasive neuroimaging technique that measures changes in blood oxygenation levels in the brain using transillumination. It is an emerging field that has gained popularity in recent years due to its real-time monitoring capabilities, low cost, portability, and patient-friendliness compared to other neuroimaging modalities such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans. The fNIRS technique utilizes near-infrared light to penetrate the skull and tissues of the scalp to reach the cortical surface of the brain, where it can detect changes in the concentration of oxygenated and deoxygenated hemoglobin, which reflects changes in neuronal activity. **[1]** The Mendi sensor is a wearable brain-sensing device that allows users to train their cognitive skills through a mobile application. It uses electroencephalography (EEG) technology to record electrical activity in the brain and provide real-time feedback to the user, enabling them to improve their cognitive performance. **[2]**

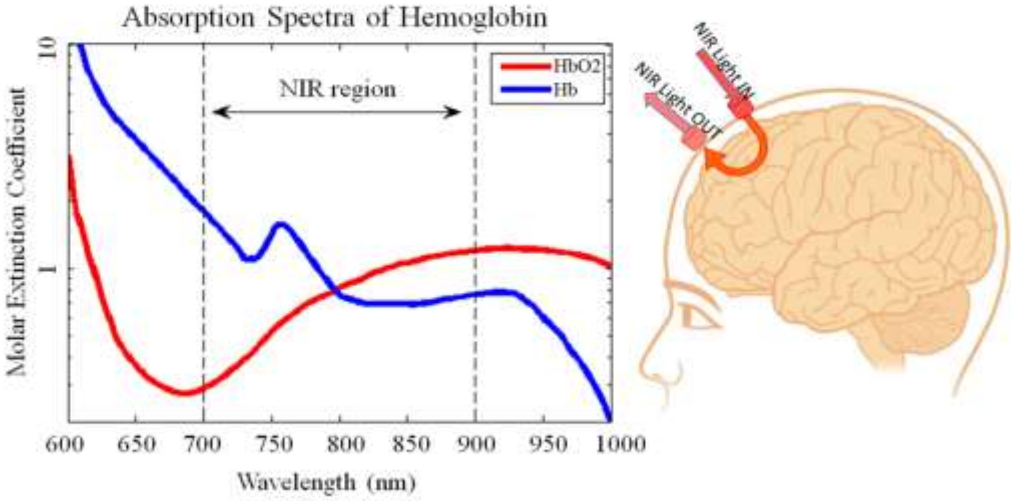

Fig. 1 Functional near-infrared spectroscopy (fNIRS)

The current neuroimaging techniques are expensive, complex, and difficult for patients to tolerate. This presents challenges in accurately diagnosing and treating Alzheimer's disease, as well as other neurological disorders like schizophrenia, dyslexia, and Parkinson's disease, due to the lack of objective and quantitative measures. While functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) have individually shown promise, their combined potential for clinical and neuroimaging research remains largely unexplored. Furthermore, the current gold standard for neuroimaging research, functional magnetic resonance imaging (fMRI), is limited by its high cost, lack of portability, and the requirement for patients to remain still during scans. Consequently, there is a pressing need for more accessible, affordable, and patient-friendly neuroimaging techniques that can provide objective measures for the accurate diagnosis and effective treatment of Alzheimer's disease and other neurological disorders. This study is aims to Investigating the potential applications of fNIRS and the Mendi sensor in clinical and neuroimaging research, Conducting experiments on human subjects to obtain data on the effectiveness of fNIRS and EEG in diagnosing neurological disorders and improving cognitive performance. Analyzing the obtained data to develop new diagnostic and therapeutic approaches for neurological disorders, as well as improving our understanding of brain function and cognitive processes. Assessing the potential benefits of using portable and user-friendly devices such as fNIRS and the Mendi sensor for clinical and research purposes, in terms of accessibility, affordability, and patient-friendliness. omparing the performance of fNIRS and EEG technologies to the current gold standard for neuroimaging research, fMRI, in terms of cost, portability, and patient tolerance. Functional near-infrared spectroscopy (fNIRS) is a relatively new imaging modality in the functional neuroimaging research arena. The fNIRS modality non-invasively investigates the change of blood oxygenation level in the human brain utilizing the transillumination technique. In the last two decades, the interest in this modality is gradually evolving for its real-time monitoring, relatively low-cost, radiation-less environment, portability, patient-friendliness, etc. Including brain-computer interface and functional neuroimaging research, this technique has some important application of clinical perspectives such as Alzheimer's disease, schizophrenia, dyslexia, Parkinson's disease, childhood disorders, post-neurosurgery dysfunction, attention, functional connectivity, and many more can be diagnosed as well as in some form of assistive modality in clinical approaches.One of the remarkable applications of fNIRS as a clinical tool is anesthetic depth monitoring. From 2009 to 2017, a wide range of investigations had been conducted by several research groups to correlate the anesthetic depth to neurovascular coupling. A complete anesthetic delivery monitoring system requires different continuous measures such as peripheral oxygenation, circulation, ventilation, and temperature [3]; those aid to assure the safety of anesthesia procedures. As an anesthetic monitoring tool to evaluate the effect of general anesthesia, a combined method (Bispectral Index monitor (BIS) [4]) includes the investigations of electroencephalographic (EEG) signals, facial electromyography (EMG), and auditory evoked potential (AEP). A combined arrangement of fNIRS and BIS is shown in Fig. Fig.1. Although this method provides the patient's anesthetized condition, it is not good enough to predict the level of anesthetic depth for proper guidance of anesthetic delivery [5, 6]. Aforesaid complaint creates scope to develop a new method that can facilitate the optimal anesthetic delivery to enhance patient safety. AD is a neurodegenerative disease that worsens over time. It is termed as a clinical state of reducing utility in several cognitive areas, like memory, thinking, visuospatial abilities, decision, executive function, praxis, and language. fNIRS may be used for detecting disease-specific variations in the brain whichever can be of therapeutic measure or diagnostic parameters. In the study of Hock et al., 38 individuals (as a guideline of the National Institute of Neurological and Communicative Disorders and Stroke criteria, 19 stable elderly people and 19 patients with a likely moderate AD [7]) were examined. This work claimed that in the case of the healthy participants, there occurred a rise in HbO2 and HbT concentration and a small decline in dHb concentration. On the other hand, most patients with AD exhibited a drop in HbO2 and HbT concentration throughout the verbal fluency test (VFT) which is a psychological test in which participants produce as many words as possible from a category in a given time. This occurrence is more prominent in the parietal cortex than in the frontal cortex.

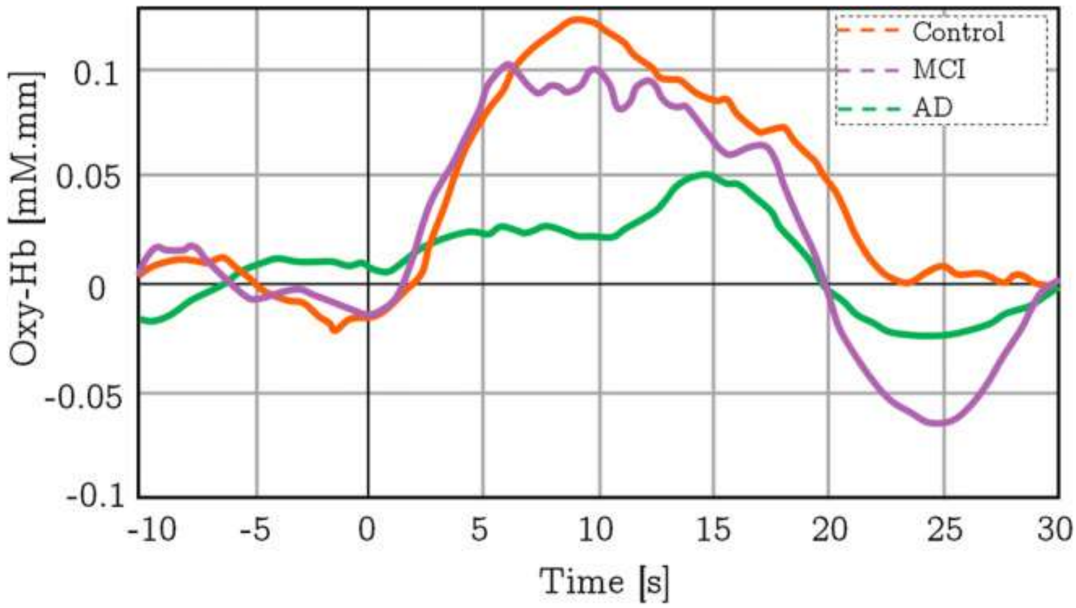

Fig.2. The overall average changes in the concentration of HbO2 of different groups during the verbal fluency test in the right parietal area of the brain. This figure is redrawn from the information found in [8]

Functional electrical stimulation (FES), which employs an electrical signal to stimulate motor neurons in particular muscle tissue, is one technique for rehabilitation [9]. FES should be implemented throughout self-regulated brain activation, to activate neuroplastic reorganization and to start learning control of the affected limbs. An optical BCI may be used to monitor the brain condition. fNIRS was used for examining the correlations of real imagery of movement. fNIRS-BCI for controlling FES and evaluating the brain function of healthy participants while self-regulated FES feedback and passive FES are being built. The opt ode setup has been selected to include a primary motor cortex in the frontal lobe that controls the upper extremity and the premotor cortex. The research study carried out by 10 healthy subjects allowed them either to visualize their right-hand extending fingers or relaxation. The time series analysis of oxygenated and deoxygenated hemoglobin demonstrated a variation in brain activity in the motor imagery when participants checked the FES compared with passively induced ones. This research demonstrates that FES alongside fNIRS could be used as a method for neuroplastic re-organization and motor therapy in a BCI environment for stroke victims.

Schizophrenia is a condition that is categorized by positive and negative symptoms and cognitive dysfunction with enduring social deficits. An assessment was done by Watanabe et al. in cerebral hemoglobin oxygen saturation in the left frontal area with 62 schizophrenia patients and 31 healthy subjects in the course of a VFT and letter-number span test (LN) measured by fNIRS [10]. Also, previous studies suggest that activities of the frontopolar prefrontal cortex in recurrent schizophrenia and their resultant biomarkers are linked to their operations. Watanabe and Kato identified that HbO2 and dHb variations were reduced in LFT between healthy controls and schizophrenia patients. This study also demonstrated improved activities and related HbO2 improvements relative to studies in patients given medication with traditional antipsychotic drugs. The corresponding changes in HbO2 concentration due to VFT and LN for the control state are given in Fig. Fig.3. The patients with schizophrenia revealed a minor peak in HbO2 concentration and a decrease in dHb concentration during VFT than controls. Alternatively, change in the concentration of HbO2 is increased during LN analogous to controls, but the relative concentration of dHb is decreased slightly from controls in schizophrenia patients. The contrast among patients who receive atypical antipsychotics and those receiving standard antipsychotics in the variations in HbO2 and dHb concentration between VFT and LN is also reported by this analysis. This further research revealed that during VFT and LN test, patients treated with atypical antipsychotics exhibited a greater rise in HbO2 concentration and a comparable reduction in dHb concentration compared with that patient were medicated with typical antipsychotics. The corresponding results are given in

Fig. Fig.4. This outcome proposes that typical antipsychotics may weaken task reaction and brain activity.

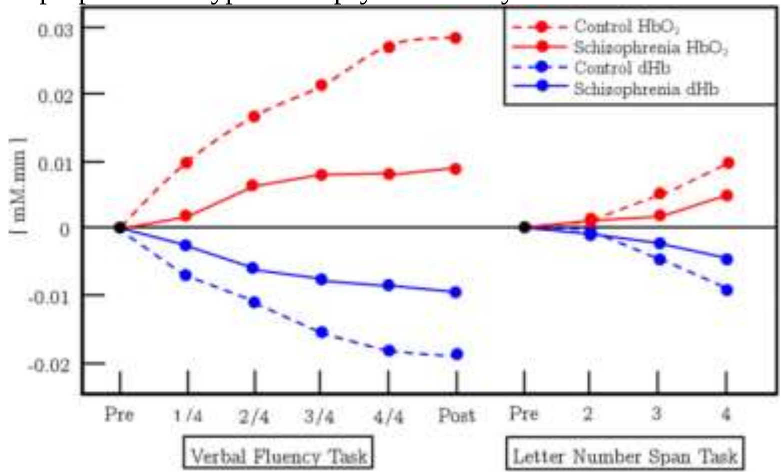

Fig.3 This figure represents the tasks (VFT and LN) and averaged change in [HbO2] and [dHb]

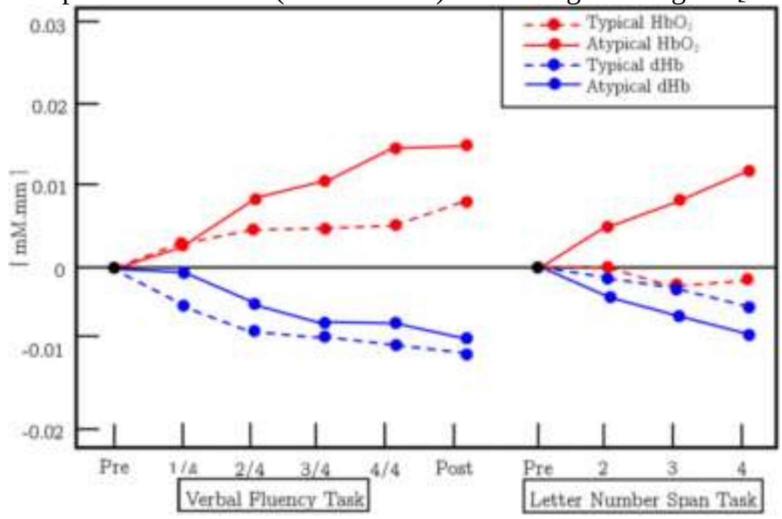

Fig..4 This figure represents the tasks (VFT and LN) and related averaged change in the concentration of HbO2 and dHb of the patients who were medicated by atypical antipsychotics and compared with the control group

Attention-deficit/hyperactivity disorder is a neurological disorder that can be present from childhood. But ADHD may pick up from adolescence and adulthood. It is a disorder that makes it difficult for a person to concentrate on and impulsive behavior control. Some warning signs for ADHD are inattention, impulsivity, non-stop talking, hyperactivity, etc. Though there is no cure for ADHD yet, current ADHD treatments may help lower symptoms and improve impulsive functioning. Some treatments include medication, education or training, therapy, or a combination of treatments. Currently, neurofeedback is frequently used in the treatment of attention-deficit/hyperactivity disorder (ADHD) which is a trouble-some and frequent disorder that strikes adults approximately 2.5–5% globally [11, 12]. NF is a comparatively new evolving technique for behavioral therapy. In this protocol, patients learn to control their specific brain activity with the help of different feedbacks such as visual, audio, or combined with real continuous-time monitoring. Fig.6 show the most affected ROI on the prefrontal cortex due to the effects of methylphenidate during the auditory oddball paradigm test by the ADHD children.

Fig.5 The most affected ROI on the prefrontal cortex due to the effects of methylphenidate during the auditory oddball paradigm test by the ADHD children

Visual facial processing weaknesses of individuals with autism spectrum disorder (ASD) may be caused by unusual brain structure and operation. Studies evaluating the asymmetric function of the brain among ASD people suggested that the lateralization of facial processing in neuro-typical (NT) individuals is less likely to be lateralized in ASD. The researchers initially tried this hypothesis using fNIRS by evaluating trends of lateralized cognitive function in facial treatment areas of the homologous temporal-occipital while observing the face of an ASD and NT group. As anticipated, as opposed to the NT participants, the ASD group demonstrated reduced human-side right hemisphere asymmetry. Judging by recent cognitive findings that robots can make it more possible for ASD to interact with human counterparts, researchers have also monitored responses to faces of robots to establish whether these stimulation trends were lateralized in each group. All groups demonstrated identical asymmetry trends for robotic faces in the exploratory study. The study suggests that human faces in ASD have lowered asymmetry as well as provide an initial basis for future tests on how the clinically useful use of conclusively different social stimuli in these populations can be [13]. In major depressive disorder (MDD), decreased oxygenation shifts in the prefrontal cortex were documented during cognitive tasks. Nonetheless, in individuals with MDD, prefrontal asymmetry was somewhat commonly investigated throughout mental exercises and their connection to suicidal thoughts. Researchers examined prefrontal asymmetry and its moderating effect in patients with MDD during mental performance between depression severity and the suicidal thoughts [14]. This project aims to investigate the potential applications of fNIRS and the Mendi sensor in clinical and neuroimaging research. The project will explore the feasibility of using these technologies to diagnose various neurological disorders such as Alzheimer’s disease, schizophrenia, dyslexia, Parkinson’s disease, childhood disorders, post-neurosurgery dysfunction, attention, functional connectivity, and others. The project will involve conducting experiments on human subjects and analyzing the obtained data. The results of this project could contribute to the development of new diagnostic and therapeutic approaches for neurological disorders, as well as improving our understanding of brain function and cognitive processes. Moreover, the use of portable and user-friendly devices such as fNIRS and the Mendi sensor can potentially increase the accessibility and affordability of neuroimaging techniques for clinical and research purposes.

METHODOLOGY

The study will follow an experimental design, where participants will be recruited and selected based on specific criteria related to the neurological disorders under investigation, such as Alzheimer's disease, schizophrenia, dyslexia, Parkinson's disease, childhood disorders, post-neurosurgery dysfunction, attention, and functional connectivity. The data collection process will involve the use of fNIRS and the Mendi sensor. fNIRS will be utilized to measure changes in blood oxygenation levels in the brain using transillumination, providing real-time monitoring of cerebral oxygenation and hemodynamics. The Mendi sensor, a wearable brain-sensing device, will be used to record electrical activity in the brain using electroencephalography (EEG) technology.

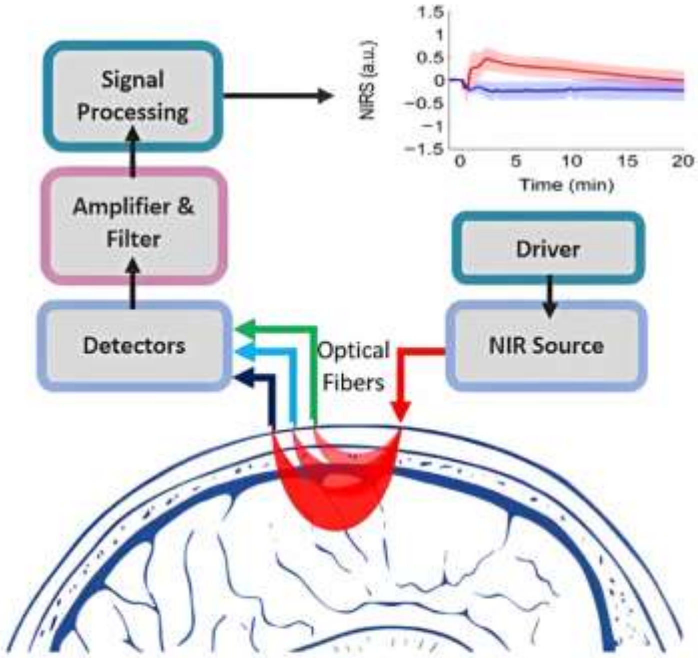

Fig.3.1 The FNIR Methodology

The participants will engage in cognitive tasks and activities through a mobile application provided by the Mendi sensor, allowing for cognitive skills training and performance improvement. Data obtained from the experiments will be analyzed using appropriate statistical methods and techniques. The analysis will involve examining the patterns of blood oxygenation changes in the brain as measured by fNIRS, as well as the electrical activity recorded by the Mendi sensor. The results will be interpreted to determine the potential diagnostic applications of fNIRS and the Mendi sensor in various neurological disorders. By conducting these experiments and analyzing the obtained data, this research aims to contribute to the understanding of the potential applications of fNIRS and the Mendi sensor in clinical and neuroimaging research. The findings will provide valuable insights into the feasibility and effectiveness of using these technologies for diagnosing neurological disorders and improving our understanding of brain function and cognitive processes.

Mendi sensor device

The Mendi sensor is a wearable brain-sensing device that allows users to train their cognitive skills through a mobile application. It utilizes electroencephalography (EEG) technology to record electrical activity in the brain. The Mendi sensor is typically worn on the forehead and connects wirelessly to a mobile device, such as a smartphone or tablet. The device captures and analyzes brainwave patterns, specifically focusing on the electrical activity related to cognitive processes. By monitoring the user's brain activity, the Mendi sensor provides real-time feedback and enables users to engage in cognitive training exercises and activities. Through the accompanying mobile application, users can participate in various cognitive tasks and games designed to enhance their cognitive skills, such as attention, memory, focus, and relaxation. The Mendi sensor tracks the user's brain activity during these activities and provides feedback to help users understand their cognitive performance and improve their skills over time. The Mendi sensor aims to provide an accessible and user-friendly way for individuals to enhance their cognitive abilities and overall mental well-being. It offers a portable and convenient solution for cognitive training, allowing users to engage in brain exercises anytime and anywhere.

Fig.3.2 The Mendi sensor

Microsoft excel software

Microsoft Excel is a popular spreadsheet software developed by Microsoft. It is part of the Microsoft Office suite of productivity tools and is widely used for organizing, analyzing, and presenting data. Excel provides a grid-based interface where users can enter and manipulate data in rows and columns. It offers various features and functionalities, including formulas, functions, charts, and graphing tools, which enable users to perform calculations, create visual representations of data, and generate reports. Excel is commonly used in businesses, educational institutions, research organizations, and personal settings for tasks such as financial analysis, data management, budgeting, project tracking, and much more. excel is a versatile software that offers several capabilities for data analysis. It enables data cleaning and preprocessing through its functions and tools, allowing for tasks such as data cleaning, outlier removal, handling missing values, and data transformation. Excel also provides various statistical functions for basic analyses, including calculating descriptive statistics like mean, standard deviation, and correlation coefficients. It supports more advanced statistical analyses through add-ins or custom formulas. In terms of data visualization, Excel offers a wide range of chart types and customization options, facilitating the creation of visually appealing graphs and plots to present data trends, patterns, and relationships. Once the data analysis is completed, Excel can be used to interpret the findings, draw conclusions, and generate reports, with the ability to present results in tables, charts, and figures within Excel itself or export them to other formats for further reporting or presentation purposes.

RESULT

It appears that the research study involved the use of the Mendi sensor device and his software to obtain and analyze results related to Al-Mustaqbal university students in specific study departments. The chapter aims to discuss the obtained results and the methodology used to acquire them.The Mendi sensor device, as previously mentioned, is a wearable brain-sensing device that allows users to train their cognitive skills through a mobile application. In this study, the Mendi sensor device was likely used to gather brain activity data from the participants.

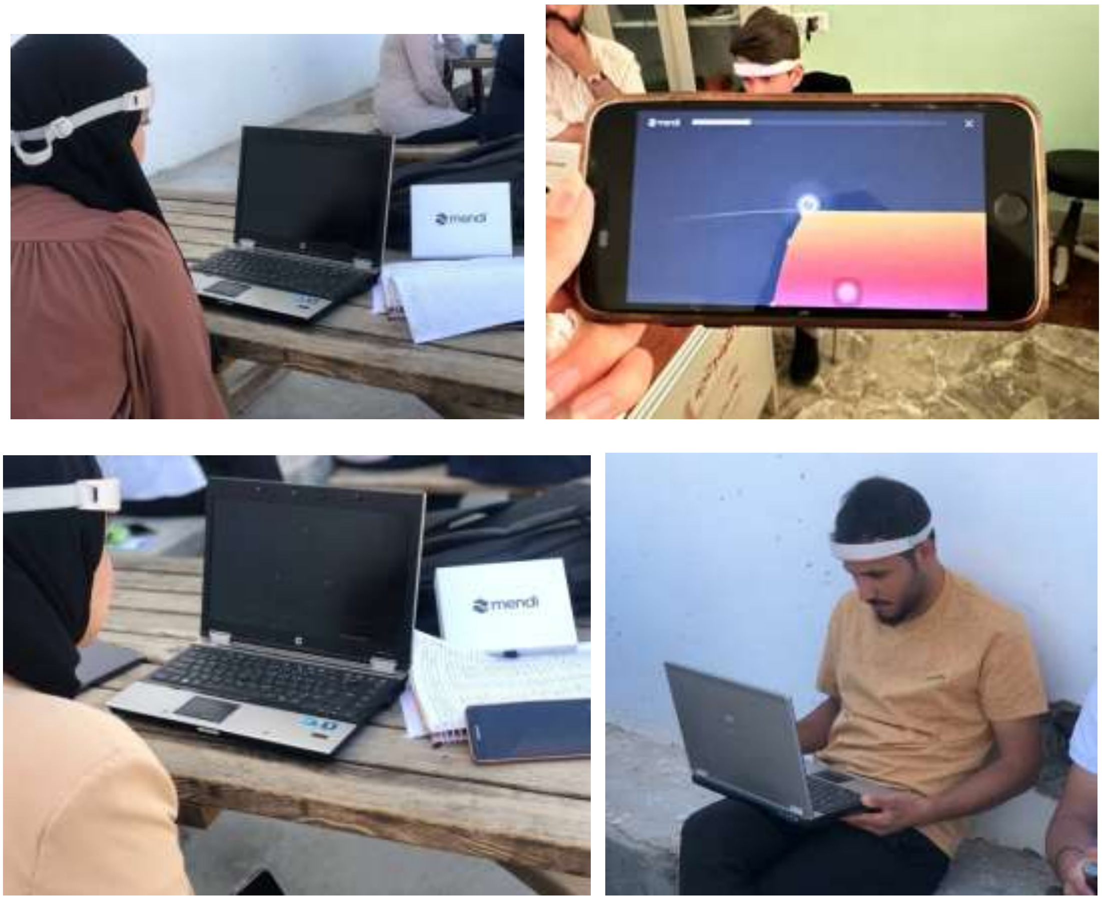

Fig. 4.1 wearable device for participant

Excel, on the other hand, is a powerful software tool widely used for data analysis, visualization, and manipulation. In this research, Excel may have been utilized to process and analyze the brain activity data obtained from the Mendi sensor device. Excel offers a range of functions and tools that can be used for data preprocessing, such as cleaning the data, handling missing values, and performing basic statistical analyses. It can also be used to create charts and graphs to visualize the data and identify patterns or trends.

Resilience (Points)	Control (Seconds)	Neural Activity%	Medications/smoking	الجنس	العمر	الاسم	ت
344P	10	10%	غير مدخن	ذكر	21	مصطفى عقيل محمد	1
1019P	20	18%	مدخن	ذكر	22	اسد عمار حسن	2
224P	10	8%	غير مدخنة	انثى	21	تبارك هيثم	3
568P	21	9%	غير مدخنة	انثى	24	نرجس علاء حسين	4
467P	8	14%	غير مدخنة	انثى	22	سفانة حاتم	5
2447P	12	112%	غيرمدخنة	انثى	21	مريم احمد	6
644P	7	13%	غيرمدخنة	انثى	26	مصابيح عبد الكريم	7
970p	18	21%	غيرمدخنة	انثى	24	مها مرتضى	9
1868P	11	37%	غيرمدخنة	انثى	21	طيبة عادل	10
1308P	11	36%	غيرمدخنة	انثى	21	فاطمة فراس	11
200P	13	13%	غيرمدخنة	انثى	21	ماريا حمزة	12
949P	27	21%	غيرمدخنة	انثى	21	فاطمة حيدر حسن	13
849P	185	25%	غيرمدخنة	انثى	22	كوثر حسين	14
449P	9	31%	غيرمدخنة	انثى	25	اخلاص علي	15
83P	32	3%	غيرمدخنة	انثى	21	زهراء حسين	16
1309P	13	37%	مدخن	ذكر	21	مصطفى رضا	17
1309P	25	24%	مدخن	ذكر	25	محمد صادق	18
912P	7	18%	غيرمدخنة	انثى	21	نور الهدى قيس	19
1486p	11	37%	غيرمدخنة	انثى	24	املية حسن	20

Fig. 4.2 Data that collected from participant

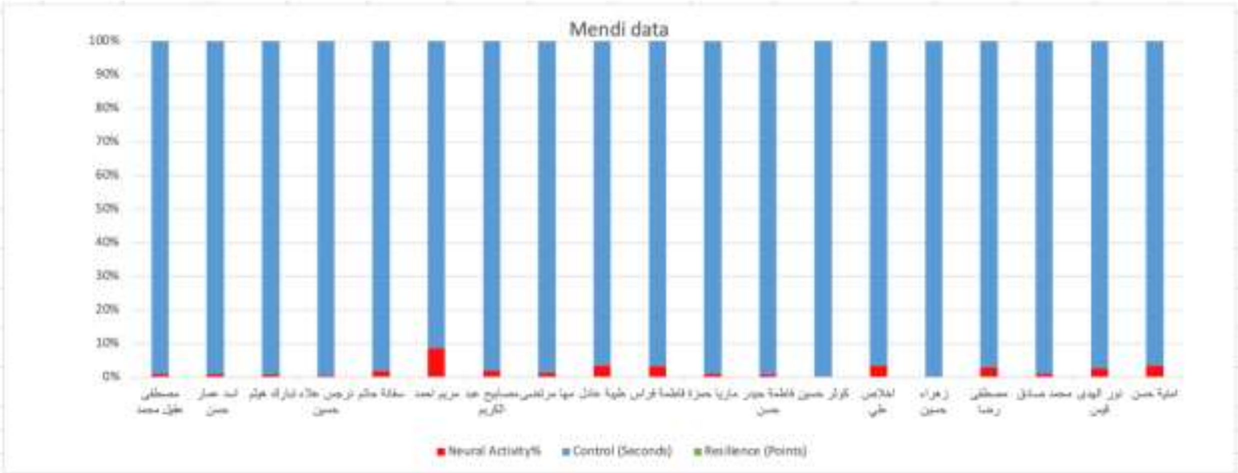

Fig. 4.3 The data vitalization for (Neural activity, Control, Resilience)

The results obtained from this study were then compared with some other data, possibly from a control group or previous research, to evaluate the effectiveness or impact of the Mendi sensor device in the context of Al-Mustaqbal University College students. The specific departments or study areas under investigation were not mentioned in the abstract, but the goal was likely to assess the cognitive performance or potential of the participants using the Mendi sensor device.

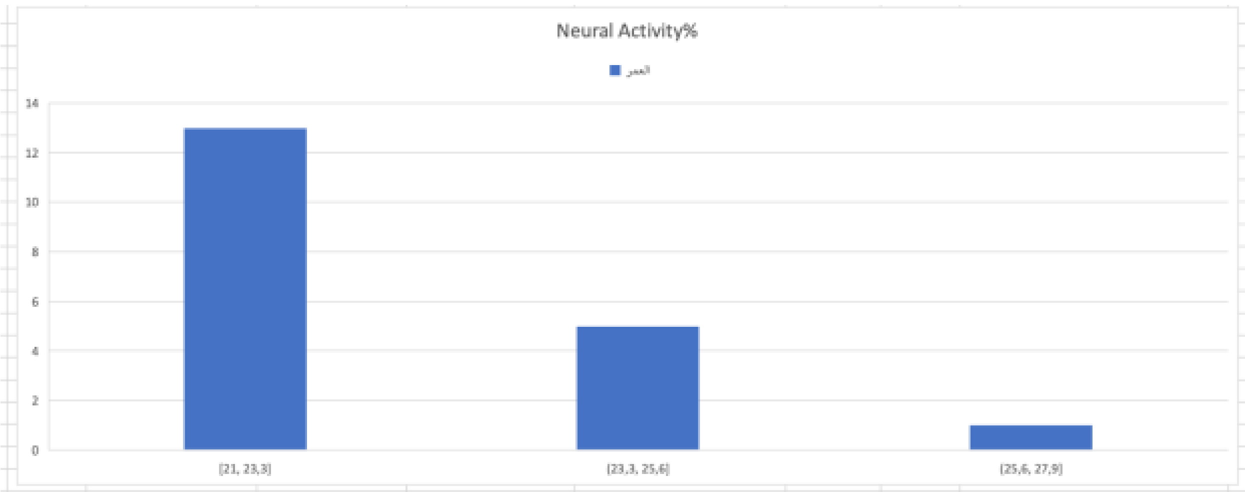

Fig. 4.4 The diagram shows the results of concentration accuracy for the ages that participated in the experiment using the sensor, noting that the ages between 23-21 are the most focused people

DISCUSSION

The results obtained from the concentration accuracy analysis of the participants in this study using the sensor indicate an interesting finding regarding age groups. Specifically, it was observed that individuals between the ages of 21 and 23 exhibited the highest levels of focus. This finding aligns with previous research suggesting that cognitive abilities and attentional capacity tend to be at their peak during young adulthood. The heightened focus observed in this age range may be attributed to factors such as enhanced cognitive processing, reduced distractions, and increased motivation and engagement. It is important to note that age-related differences in concentration accuracy may be influenced by various factors, including neurological development, life experiences, and individual differences in cognitive abilities. Further investigation is required to better understand the underlying mechanisms contributing to the observed differences in concentration accuracy across age groups. These findings have implications for the application of the sensor technology in various contexts. By identifying the age range with the highest levels of focus, the sensor can be optimized for targeted interventions, such as cognitive training programs or attention-enhancement techniques. Additionally, these results highlight the importance of considering age as a factor in future studies involving the sensor and its potential applications in clinical and educational settings. It is important to acknowledge that concentration accuracy is a complex construct influenced by multiple factors beyond age alone. Future research should explore additional variables, such as gender, cognitive abilities, and environmental factors, to provide a more comprehensive understanding of concentration accuracy across different populations.

CONCLUSION

Through conducting experiments on human subjects and analyzing the obtained data, this project aimed to explore the feasibility of using fNIRS and the Mendi sensor for diagnosing various neurological disorders, including Alzheimer's disease, schizophrenia, dyslexia, Parkinson's disease, childhood disorders, post-neurosurgery dysfunction, attention issues, and functional connectivity impairments. The results of this study are expected to contribute to the understanding of the potential applications of fNIRS and the Mendi sensor in clinical and neuroimaging research. By demonstrating the efficacy and reliability of these technologies in diagnosing neurological disorders, this research has the potential to lead to the development of new diagnostic and therapeutic approaches. Furthermore, the use of portable and user-friendly devices like fNIRS and the Mendi sensor could increase the accessibility and affordability of neuroimaging techniques for both clinical and research purposes. Overall, this study has provided valuable insights into the potential benefits and applications of fNIRS and the Mendi sensor, paving the way for further advancements in clinical and neuroimaging research.

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