Exploring the Potential of Touch-Based Behavioral Bioinformatics for Early Detection of Neurological Disorders: A Computational Perspective on Datasets and Methods.

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1 Abstract

Parkinson's disease and autism spectrum disorder are two neurological conditions that can significantly influence a person's life and are challenging to diagnose early. However, these illnesses' early detection and diagnosis have shown promising outcomes thanks to recent developments in touch-based bioinformatics. In this work, we examine the potential of touch-based bioinformatics from a computational standpoint for the early diagnosis of neurological illnesses. We concentrate on data sets and their analysis to find touch-based biomarkers that can shed light on the earliest stages of neurological diseases.

2 Introduction

Technology is becoming an increasingly important part of our lives. Whether we talk about access to essential services such as healthcare, emergency services, food, transportation, and more, everything in the 21st century is done through technology. The use of technology ensures efficiency and allows us to distribute goods, services, and more to a broader population. Technology has completely changed and revolutionized our world. This revolution is ongoing, and technology will only become a more intrinsic part of our daily lives.

One of the by-products of technology is the vast amount of private and public data it generates. The data generated by technology is beneficial as it can be used to improve existing technology, look for patterns in a particular domain, and find new and creative solutions to existing and upcoming problems. Over the years, the healthcare sector is undergoing a significant transformation, with technology and data becoming increasingly essential tools for healthcare professionals. As a result, there has been a growing trend toward adopting digital technologies, big data, and machine learning in the healthcare industry in recent years. These technologies offer immense potential for improving the quality and efficiency of healthcare delivery, enhancing patient outcomes, and enabling early diagnosis and treatment of diseases.

The authors of several studies have provided sufficient evidence that using technology to identify early signs of neurological disorders can significantly improve diagnosis and treatment outcomes. In the article titled *"Bioinformatics Approach to Identify Significant Biomarkers, Drug Targets Shared Between Parkinson's Disease and Bipolar Disorder: A Pilot Study"*, the authors, Hossain et al. (2022) discuss using bioinformatics to identify biomarkers and drug targets shared between Parkinson's disease and bipolar disorder. This article specifically addresses the use of data and technology in the context of neurological disorders [1].

There are countless other research articles and evidence that shed some light on how the healthcare sector is making use of technological tools and data for the betterment of its patient and making diagnoses more accurate and reliable. For the detection and diagnosis of neurological illnesses like Parkinson's disease and autism spectrum disorder, the healthcare industry is relying more on technology and data. Academics have emphasized touch-based bioinformatics as being crucial in diagnosing various ailments early. Several studies have looked into the potential of this method. For instance, Shen et al. (2018) employed behavioural data and machine learning models to identify patients' early indicators of Parkinson's disease precisely [2]. In a similar vein, research by Simeoli et al. (2021) showed that touch-based tasks have the potential to be used to spot early signs of autism spectrum conditions [3]. Also, Hossain et al. (2022) study employed big data and machine learning to find biomarkers for Parkinson's disease and bipolar disorder.

3 Literature Review

Applying cutting-edge technology and data-driven strategies is causing the healthcare industry to evolve swiftly. As a result, the use of these instruments in the diagnosis and treatment of various neurological illnesses has drawn increasing attention in recent years. With a particular emphasis on touch-based bioinformatics, this literature review examines how technology and data are used to identify neurological illnesses in their early stages. We will look at various studies that use big data, touch-based behavioural informatics, and machine learning models to diagnose and categorize neurological conditions such as Parkinson's disease, autism spectrum disorder, diabetic peripheral nephropathy, and bipolar disorder. The review will emphasize touch-based bioinformatics' promise for early detection and diagnosis, drawbacks, and future applications.

Understanding the most common neurological disorders and the conventional and modern methods used to diagnose and treat them is crucial to comprehend the potential of technology and touch-based behavioural bioinformatics in detecting and mitigating neurological disorders. Some of the most common and incapacitating neurological disorders impacting people globally include Parkinson's disease, Alzheimer's disease, and autism spectrum disorder. These illnesses frequently exhibit a variety of symptoms, which can complicate diagnosis and cause therapy to be delayed. Conventional diagnostic techniques, such as neurological exams and brain imaging scans, have drawbacks and might only sometimes be sensitive enough to identify the earliest indications of neurological problems. Additionally, current treatments frequently concentrate on symptom management rather than attempting to find a solution for these conditions.

3.1 Behavioral Informatics and Data-Driven Technology in Neurological Disorder Diagnosis: A Review of the Literature

In response to these difficulties, researchers have developed more precise and effective diagnostic and therapeutic approaches using technology and data-driven methods, such as touch-based behavioural bioinformatic and machine learning models. With a focus on touch-based behavioural bioinformatics, we will examine recent developments in technology and data in diagnosing and treating neurological illnesses in this literature review.

The article *"Identification of Immune Infiltration and the Potential Biomarkers in Diabetic Peripheral Neuropathy Through Bioinformatics and Machine Learning Methods"*, by Li et al. (2022), utilizes bioinformatics and machine learning models to identify immune infiltration and potential biomarkers in diabetic peripheral neuropathy. The authors used datasets from The Cancer Genome Atlas and Gene Expression Omnibus to develop and validate their model, highlighting the potential for using large datasets to improve early neuropathy diagnosis [4].

"An Empirical Analysis of Ensemble Systems in Cancellable Behavioural Biometrics: A Touch Screen Dataset" by Damasceno and Canuto (2014) explores the use of touch-based behavioural biometrics to develop ensemble systems for authentication purposes. While not directly related to neurological disorder diagnosis, the study highlights the potential for touch-based technology in healthcare applications [5].

"Category learning in rodents using touchscreen-based tasks" by Broschard et al. (2020) discusses the use of touchscreen-based tasks in rodent models to study the neurological mechanisms underlying category learning. The study highlights touch-based technology's potential in basic and clinical neuroscience research [6].

Another article titled *"Using Technology to Identify Children With Autism Through Motor Abnormalities"*, by Simeoli et al. (2021), explores the use of technology to identify early signs of autism spectrum disorder through motor abnormalities. The authors used a touchscreen-based task to assess motor performance, highlighting the potential for touch-based technology in the early diagnosis of neurological disorders [3]. Autism Spectrum Diagnosis using touch-based Behavioral Bioinformatics is an exploding area of research. Numerous datasets are available where touch input devices were used to generate data and then analyze the dataset to see if it yields any positive results. One such study titled *"Using a small dataset to classify strength-interactions with an elastic display a case study for the screening of autism spectrum disorder"*, by Monarca et al. (2022) explores the use of touch-based technology in the screening of autism spectrum disorder. The authors used a small dataset to classify strength interactions with a flexible display. They found promising results for using touch-based technology to detect autism spectrum disorder [7].

Furthermore, Billing et al. (2020) article titled *"The Dream Dataset-Supporting a Data-Driven Study of Autism Spectrum Disorder and Robot Enhanced Therapy"* discusses the use of the Dream Dataset to study autism spectrum disorder and robot-enhanced therapy. The study highlights the potential for large datasets to support data-driven studies of neurological disorders. The study article collects data from various sources, including clinical assessments, medical records, and demographics. The dataset facilitates the research community's efforts to develop and evaluate autism spectrum disorder (ASD) screening tools and interventions. The authors also describe how they used the dataset to study the effectiveness of robot-enhanced therapy as a treatment for ASD. This study demonstrates the potential for large datasets to support data-driven studies of neurological disorders and the value of using technology to enhance therapy and treatment options [8].

Due to their capacity to evaluate enormous datasets and spot patterns that may take time to be evident to human analysts, machine learning and data-driven approaches are quickly becoming indispensable in the healthcare industry. Machine learning algorithms can aid in extracting valuable insights from the growing body of medical data, resulting in better patient diagnoses and treatment alternatives. As a result, machine learning and data-driven approaches have entirely transformed the healthcare industry and substantially improved patient outcomes [2]. The article, *"Translational Informatics for Parkinson's Disease-From Big Data to Small Actionable Alterations"* by Shen et al. (2019), explores the use of big data and machine learning models to identify minor, actionable alterations in the treatment of Parkinson's disease. The authors highlight the potential for using large datasets and machine learning models to improve early diagnosis and treatment of neurological disorders [2].

"The Bioinformatics Approach to Identify Significant Biomarkers, Drug Targets Shared Between Parkinson's Disease and Bipolar Disorder: A Pilot Study", by Hossain et al. (2022) is also another prime example of how data-driven methodologies and machine learning can play a crucial role in improving healthcare outcomes for neurological disorders. By utilizing a bioinformatics approach to identify shared biomarkers and drug targets between Parkinson's disease and bipolar disorder, the study demonstrates the potential for improving early diagnosis and personalized treatment options. This approach can potentially revolutionize how we approach neurological disorders, moving away from a one-size-fits-all approach and towards a more tailored and customized approach to treatment. In addition, the study highlights the importance of using advanced technologies and data-driven strategies to understand and treat neurological disorders [1].

3.2 The Role of Touchscreen Technology in Cognitive Assessment: A Review of the Literature

In our previous section, we have established the importance of technology and machine learning in healthcare, as well as gained a basic understanding of neurological disorders and their traditional diagnostic methods; the following articles focus specifically on the use of data, big data, and machine learning in the context of touch-based behavioural informatics for the diagnosis of neurological disorders. These studies highlight the potential for touch-based technology to improve the accuracy and efficiency of neurological disorder diagnosis and pave the way for personalized and targeted treatment plans. The following sections will detail the findings and methodologies of these studies.

"A Touchscreen Motivation Assessment Evaluated in Huntington's Disease Patients and R6/1 Model Mice" by Heath et al. (2019) examines the feasibility and validity of using a touchscreen cognitive assessment battery to detect cognitive decline in individuals with early-stage Huntington's disease. The study found that the touchscreen battery was sensitive to cognitive impairments in these individuals and provided a valuable tool for assessing cognitive function in this population [9].

"Touchscreen games to detect cognitive impairment in senior adults. A user interaction pilot study" by Valladares-Rodriguez et al. (2019) explores the use of games and touchscreen technology to assess cognitive function in individuals with cognitive impairment and dementia. The study found that touchscreen-based game assessments were feasible and acceptable to participants and provided a reliable measure of cognitive function, which could be used in research and clinical settings [10].

"Touchscreen Cognitive Tools for Mild Cognitive Impairment and Dementia Used in Primary Care Across Diverse Cultural and Literacy Populations: A Systematic Review" by Giaquinto, Battista and Angelelli (2022) discusses the potential of touchscreen-based neurocognitive assessment tools for use in primary care settings. The study found that touchscreen assessments were well-tolerated by patients and provided a quick and reliable evaluation of cognitive function [11].

"Touchscreen typing-pattern analysis for detecting fine motor skills decline in early-stage Parkinson's disease" by Iakovakis et al. (2018) examines the feasibility of using a touchscreen-based motor assessment tool to evaluate the motor symptoms of Parkinson's disease. The study found that the touchscreen tool was sensitive to motor deficits in individuals with Parkinson's disease and provided a convenient and objective measure of motor function [12].

"Can Touch Screen Tablets be Used to Assess Cognitive and Motor Skills in Early Years Primary School Children? A Cross-Cultural Study" by Pitchford and Outhwaite (2016) investigates the use of touchscreen tasks for assessing cognitive function in children. The study found that touchscreen tasks were well-tolerated by children and provided a reliable measure of cognitive function compared to traditional neuropsychological methods [13].

3.3 Limitations and Future Directions

Although the studies discussed in this literature review show the potential of touch-based behavioural informatics and data-driven technologies for the early detection and diagnosis of neurological disorders, there are limitations to consider. For example, many studies are small-scale, and larger, more diverse samples are needed to validate the findings. Additionally, more research is required to determine the most effective touch-based tasks for assessing specific neurological disorders and develop standardized protocols for administering these tasks.

Future research should focus on validating touch-based assessments in larger, more diverse samples and developing standardized protocols for administering these tasks. Additionally, research should explore the potential for using machine learning algorithms to analyze the large datasets generated by touchscreen assessments, which could lead to more accurate and efficient diagnostic tools. Furthermore, research should investigate the potential for using touch-based estimates to monitor the progression of neurological disorders and evaluate the effectiveness of interventions.

In conclusion, the literature supports the potential of touch-based behavioural informatics and data-driven technologies for the early detection and diagnosis of neurological disorders. Touchscreen assessments provide a convenient, accessible, and objective measure of cognitive and motor performance, making them well-suited for use in research and clinical settings. Furthermore, using machine learning algorithms to analyze the large datasets generated by touchscreen assessments could lead to the development of more accurate and efficient diagnostic tools, ultimately improving patient outcomes and the quality of healthcare delivery.

In the following sections, we will build upon the evidence presented in this literature review by incorporating findings from the discussed studies and additional resources to explore further and analyze the use of touch-based behavioural informatics and data-driven technologies in the early detection and diagnosis of neurological disorders.

4 Innovative Approaches in Neurological Disorder Detection and Intervention

Numerous cutting-edge technologies and approaches are now being used in neurological illness diagnosis and treatment, as of neurological illness diagnosis and treatment, as was emphasized in the literature study. With an emphasis on touch-based behavioural informatics and data-driven techniques, this section gives an overview of these technologies and processes.

4.1 Utilizing Touch Interactions for Neurological Disorder Detection

Touch-based behavioural informatics has emerged as a promising approach to the early detection and diagnosis of neurological disorders. By analyzing the subtle changes in touch and motor interactions, these methods can provide valuable insights into a patient's cognitive and motor functioning. Some of the critical studies mentioned in the literature review that employed touch-based behavioural informatics are as follows:

- Iakovakis et al. (2018) utilized touchscreen typing-pattern analysis to detect fine motor skills decline in early-stage Parkinson's disease [12].

- Simeoli et al. (2021) investigated using technology to identify children with autism spectrum disorder through motor abnormalities using a touchscreen-based task [3].
- Heath et al. (2019) examined the feasibility and validity of using a touchscreen cognitive assessment battery to detect cognitive decline in individuals with early-stage Huntington's disease [9].
- Valladares-Rodriguez et al. (2019) explored using games and touchscreen technology to assess cognitive function in individuals with cognitive impairment and dementia [10].

These studies demonstrate the potential of touch-based behavioural informatics in improving the accuracy and efficiency of neurological disorder diagnosis, paving the way for personalized and targeted treatment plans.

4.2 Leveraging Data Science for Neurological Disorder Diagnosis and Treatment

Data-driven approaches, including big data and machine learning, have also revolutionized how neurological disorders are diagnosed and treated. These methods can significantly improve early diagnosis and treatment outcomes by analyzing large datasets and identifying patterns. Some of the critical studies mentioned in the literature review that employed data-driven approaches are as follows:

- Shen et al. (2019) explored the use of big data and machine learning models to identify minor, actionable alterations in the treatment of Parkinson's disease [2].
- Hossain et al. (2022) used a bioinformatics approach to identify shared biomarkers and drug targets between Parkinson's disease and bipolar disorder [1].
- Li et al. (2022) utilized bioinformatics and machine learning methods to identify immune infiltration and potential biomarkers in diabetic peripheral neuropathy [4].

These studies showcase the potential of data-driven approaches in revolutionizing the field of neurological disorder diagnosis and treatment, moving from traditional methods to more tailored and personalized strategies.

Throughout this paper, we have examined numerous resources that emphasize the potential of innovative approaches in neurological disorder detection and intervention. For example, Touchscreen technology, as evidenced by studies conducted by Simeoli et al. (2021) and Iakovakis et al. (2018), has shown great promise in early detection and diagnosis of conditions such as autism spectrum disorder and Parkinson's disease through the assessment of motor and cognitive abnormalities. Furthermore, data-driven approaches like machine learning and extensive data analysis have demonstrated their effectiveness in improving healthcare outcomes for neurological disorders, as seen in studies by Shen et al. (2019) and Hossain et al. (2022). These studies underscore the value of combining advanced technology and data-driven strategies to revolutionize how we approach neurological disorders and move toward more personalized and targeted treatment plans. By integrating these innovative approaches, neurological disorder detection and intervention can continue to evolve, enhancing our ability to diagnose, treat, and ultimately improve the quality of life for those affected by these conditions.

Current technologies and methodologies, such as touch-based behavioural informatics and data-driven approaches, have significantly advanced the field of neurological disorder diagnosis and treatment. Building on the findings from the studies discussed in the literature review and incorporating additional resources, further exploration and analysis of these technologies and methodologies can lead to even more significant improvements in early detection and diagnosis of neurological disorders.

5 Methodological and Technological Limitations and Improvements

In neurological disorders, the effectiveness of diagnosis and treatment relies heavily on the methodologies and technologies employed. Despite significant advancements, several limitations and challenges remain that need to be addressed to improve the management of these disorders further [2–5]. This section discusses the methodological and technological limitations and improvements identified and proposed in recent literature. By understanding and addressing these limitations, researchers and healthcare providers can work towards more accurate and effective diagnosis and treatment of neurological disorders.

5.1 Methodological Limitations

One of the primary methodological limitations in neurological disorders is the need for standardized assessment tools that can be readily applied across different patient populations and clinical settings [6, 9]. Furthermore, many cognitive tests have limited translational value, making bridging the gap between preclinical and clinical research difficult. Additionally, there is a need for more advanced bioinformatics approaches to identify significant biomarkers and drug targets shared between related neurological disorders, such as Parkinson's disease and bipolar disorder [1]. Finally, developing and validating new assessment tools should consider patients' diverse cultural and literacy backgrounds and the unique challenges associated with different clinical settings [10, 11].

5.2 Technological Limitations

A major technological limitation is the reliance on small datasets, which can limit the general reliability and robustness of machine learning models developed for diagnostic and therapeutic purposes [7]. To overcome this challenge, researchers should focus on collecting more extensive and diverse datasets and developing novel data augmentation techniques to increase the size and variety of available data. This would help improve the performance of machine learning algorithms and enable more accurate and reliable detection of neurological disorders [7]. Furthermore, there is a need for more in-depth studies examining the potential role of immune cell infiltration in the parthenogenesis of diabetic peripheral neuropathy and other neurological disorders [4].

5.3 Methodological Improvements

Touchscreen-based tasks are a potential solution to the need for standardized assessment tools. They allow for more excellent stimulus presentation and task design flexibility and can be easily adapted to various populations and settings [6]. Moreover, using advanced bioinformatics approaches could facilitate the development of more targeted and effective therapeutic interventions for related neurological disorders, such as Parkinson's disease and bipolar disorder [1].

5.4 Technological Improvements

To address the limitations of small datasets, researchers should focus on collecting more extensive and diverse datasets and developing novel data augmentation techniques [7]. This would help improve the performance of machine learning algorithms, enabling more accurate and reliable detection of neurological disorders. Furthermore, studies examining the potential role of immune cell infiltration in the parthenogenesis of neurological disorders, such as diabetic peripheral nephropathy, could help to understand their underlying mechanisms better and inform the development of novel therapies [4].

Several methodological and technological limitations have been identified, offering opportunities for improvement in neurological disorders. Addressing these limitations through the development of standardized, touchscreen-based assessment tools, the collection of more extensive and more diverse datasets, the use of advanced bioinformatics approaches to identify biomarkers and drug targets, and the consideration of various cultural and literacy backgrounds in the development of new assessment tools will contribute to more accurate and effective diagnosis and treatment of neurological disorders.

6 A Comparative Analysis of Touch-based Behavioral Biometric Approaches for Diagnosing Neurological Disorders

Recent studies utilize touch-based behavioural biometrics for diagnosing or detecting neurological disorders. We will primarily focus on three articles [14–16], which encompass a diverse range of approaches, including multimodal classification of Parkinson's disease using differential delay analysis [14], a comprehensive survey of machine learning-based methods for predicting neurological disorders [15], and the detection of motor impairment in Parkinson's disease via mobile touchscreen typing [16].

Each article offers valuable insights and quantitative data, including mathematical equations, diagrams, and other visual aids. We will critically examine and compare the methods and techniques presented in these articles to better understand the current state of touch-based behavioural biometrics in neurological disorders. Furthermore, we will identify potential areas for improvement and future research directions, highlighting the strengths and limitations of the different approaches under investigation.

6.1 Multimodal Classification Using Delay Differential Analysis

The classification performance of methods presented in "Multimodal Classification of Parkinson's disease using differential delay analysis" [14] and its relevance to our topic of touch-based behavioural biometrics for diagnosing neurological disorders. The study compares 64-channel EEG and behavioural data classification performance for detecting Parkinson's disease in perturbation and no-perturbation tasks.

The authors found that the classification performance was dependent on electrode location and task (p ¡ 0.00001) [14]. The maximum A' for perturbation trials was 0.75, while for the no-perturbation tests, it was 0.74. Behavioural classification outperformed EEG classification, with a top A' of 0.80 for both perturbation and no-perturbation trials. The z-position (depth) provided a robust type in both experimental paradigms, indicating task invariance. However, classification performance was dependent on both the behavioural modality and the task (p ¡ 0.00001) [14].

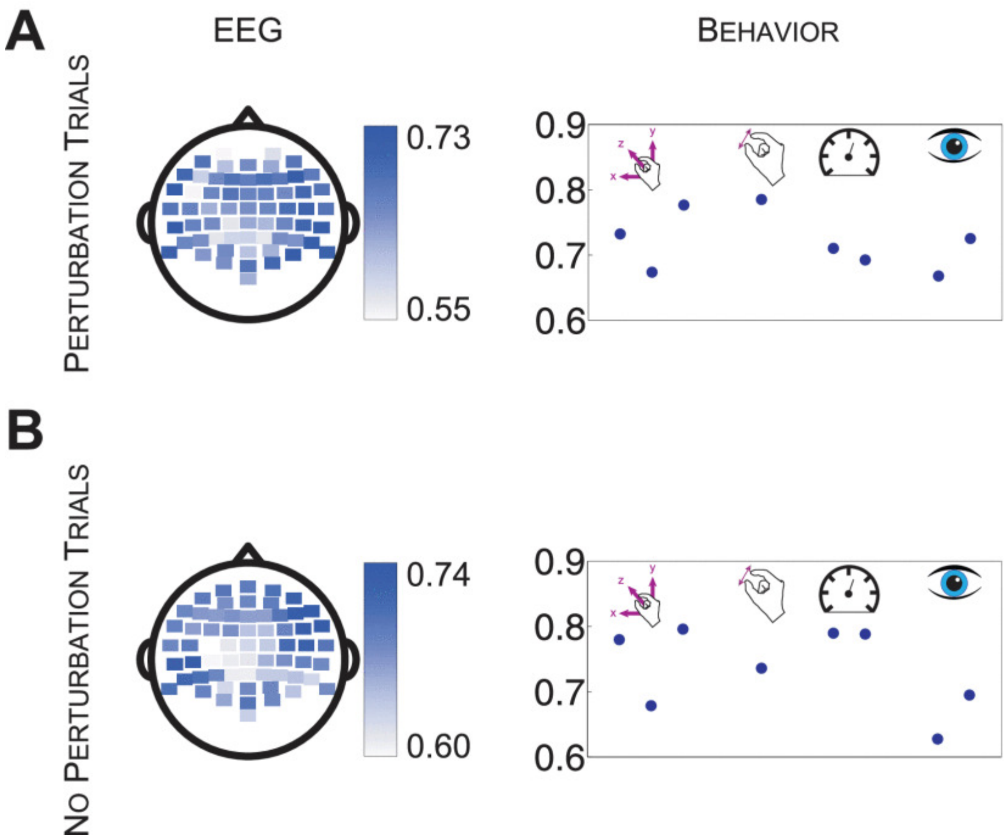

Figure 1: DDA classification of EEG and behavioural data. The classification performance A' for the 64-electrode EEG (left) for binary classification of perturbation (top) and no-perturbation (bottom) experimental paradigms. The colour scale next to each cap indicates the colour representation of classification performance. The classification for behaviour is shown on the right for each of the eight behavioural channels grouped according to kinematic metric and indicated by the icons. Adapted from [14].

The top-performing models and delay pairs for EEG and behavioural data were significantly different across kinematic metric groupings, suggesting that they are dynamically distinct and operate at different temporal scales [14]. The combination of EEG and behavioural data provided a statistically significant improvement in classification performance over EEG data alone (p ¡ 0.00001) [14]. For the perturbation task, the combined classification resulted in an A' of 0.82, compared to A' = 0.72 for EEG and A' = 0.52 for behaviour only. For the no-perturbation task, the combined classification yielded an A' of 0.84, compared to A' = 0.76 for EEG and A' = 0.63 for behaviour only [14].

The potential benefits of combining EEG and behavioural data for diagnosing Parkinson's disease using touch-based biometrics. The improved classification performance achieved by combining these data types highlights the importance of exploring multimodal approaches for detecting neurological disorders. Furthermore, this insight can inform the development of more accurate and reliable touch-based biometric systems for diagnosing neurological disorders in the future.

6.2 Machine Learning-Based Approaches for Neurological Disorder Predictions

"A Survey of Machine Learning-Based Approaches for Neurological Disorders Predictions" [15]. The authors discuss various machine learning techniques, including Support Vector Machines, Artificial Neural Networks, Bagging, Boosting, and Random Forest, which have been applied to predict and diagnose neurological disorders such as Alzheimer's disease, Schizophrenia, and Parkinson's disease. One of the key takeaways from this article is the effectiveness of various machine learning techniques in predicting neurological disorders.

The authors comprehensively summarize the methods used for each condition in Table 1: Summary of the Machine Learning-based Methods for Neurological Disease Prediction [15]. This table highlights the wide range of techniques used and their respective accuracies, providing insights into the potential of machine learning in the early diagnosis and management of neurological disorders. In the case of Schizophrenia, the authors present various studies that have successfully used ensemble methods, SVM, and other machine learning techniques to achieve accuracies between 83% and 96% [15]. These high prediction accuracies may contribute to improved care and management for Schizophrenia patients, as early detection and intervention can help prevent serious complications.

For Parkinson's disease, the article highlights supervised learning techniques such as SVM, Random Forest, and Naïve Bayes, achieving impressive F-measures of up to 0.97 for SVM and 0.95 for RF [15]. The authors also discuss using voice dataset-based prediction methods that achieve high accuracy of 95.89% using ANN models [15]. These results indicate that machine learning can play a vital role in early diagnosis and understanding of the genetic causes of Parkinson's disease.

In the context of Alzheimer's disease, the authors discuss several studies that have employed machine learning techniques such as Support Vector Machines, Convolutional Neural Networks, and Deep Learning to achieve high prediction accuracies ranging from 88% to 99.21% [15]. These findings demonstrate the promising potential of machine learning in early detection and intervention for Alzheimer's disease, which could help slow its degenerative effects. In the case of Schizophrenia, the authors present various studies that have successfully used ensemble methods, SVM, and other machine learning techniques to achieve accuracies between 83% and 96% [15]. These high prediction accuracies may contribute to improved care and management for Schizophrenia patients, as early detection and intervention can help prevent serious complications.

For Parkinson's disease, the article highlights supervised learning techniques such as SVM, Random Forest, and Naïve Bayes, achieving impressive F-measures of up to 0.97 for SVM and 0.95 for RF [15]. The authors also discuss using voice dataset-based prediction methods that achieve high accuracy of 95.89% using ANN models [15]. These results indicate that machine learning can play a vital role in early diagnosis and

understanding of the genetic causes of Parkinson's disease.

Table 1: Summary of the Machine Learning-based Methods for Neurological Disease Prediction. Adapted from [15]

Author's Name	**Data Description**	**Data Source**	**Machine Learning Methods**
Esther et al. (2021)	T1-weighted MRI	ADNI	SVM, CNN
Morshedul et al. (2021)	MR Images	OASIS	SVM, Logistic Regression, DT, RF
Hina et al. (2020)	T1-weighted MRI	ADNI	CNN, KNN, SVM, RF
Caihua et al. (2022)	T1-weighted MRI	NA-ADNI	CNN, SVM
Daniel et al. (2020)	MR Images	ADNI	MLP, CBLST
Filippo et al. (2019)	Motion dataset	IPMP-MS	SVM, RF, NB
Gunjan et al. (2018)	Speech dataset	UCI	MLP, SVM, KNN
Zehra et al. (2020)	Speech dataset	National Centre for Voice and Speech	RT, ANN, SVM
C. Salvatore (2014)	T1-weighted MRI	UPDRS	SVM
Indrajit et al. (2012)	Speech dataset	-	LR, RF, SVM
Geetha et al. (2022)	sMRI	Institute of Mental Health, Singapore	Ensemble methods
Bae et al. (2021)	Social media text	-	SVM, RF, NB, LR
Ke et al. (2021)	Multimodal data	Guangzhou Medical University	SVM, LR, KNN
Lin et al. (2021)	Clinical, Cognitive functions	China Medical University Hospital	MFNN, SVM
Chand et al. (2020)	sMRI and clinical procedures	US, German and Chinese cohorts	HYDRA

The high accuracies achieved in these studies demonstrate the potential of machine learning for improving early detection, intervention, and overall patient care for people suffering from neurological disorders.

6.3 Detection of Motor Impairment in Parkinson's Disease via Mobile Touchscreen Typing

In the article titled "Detection of Motor Impairment in Parkinson's Disease Via Mobile Touchscreen Typing" by Teresa Arroyo-Gallego et al. [16], the authors have conducted a study to detect Parkinson's Disease (PD) based on typing signals collected from a population of 24 people diagnosed with PD and 27 healthy controls. They developed a custom screen keyboard to enable typing data collection. They implemented a three-phase data analysis method involving signal conditioning, feature extraction, and evaluating the feature vector for detecting PD status.

In the signal conditioning phase, the typing signal $X[t]$ is defined as the sequence of flight time (FT) values corresponding to each key tap. The typing data is further processed to remove noise and minimize the effect of confounding factors. The following equation is used to normalize the signal:

$$X'[t] = X[t] - \bar{X} : X' \in [\theta_A, \theta_B] \tag{1}$$

The normalized signal is represented by X', with θ_A and θ_B defining the estimated range of values in which 99

$$X'_{Si}[t, N] = X'[t]w[t - iN] \tag{2}$$

In the feature extraction phase, the authors evaluate X'_S using distribution and covariance-based approaches, defining two feature families: skewness, kurtosis, and covariance. The skewness (Sk_i) and kurtosis (Kt_i) descriptors are computed as follows:

$$Sk_i = \frac{\sum^{M_i} m = 1 \left(X'Si[m] - \bar{X}'_{Si}\right)^3}{\sigma^3_{Si}} \tag{3}$$

$$Kt_i = \frac{\sum^{M_i} m = 1 \left(X'Si[m] - \bar{X}'_{Si}\right)^4}{\sigma^4_{Si}} - 3 \tag{4}$$

The typing signal structure X'_S is transformed into a matrix (H) by applying Kernel Density Estimation (KDE), and the corresponding covariance matrix (COVH) is estimated for the resulting NFT distribution matrix (H) as follows:

$$COV_{H_{i,j}} = cov(H_{i*}, H_{j*}) = \frac{1}{L-1} \sum^{L} l = 1 \left(Hi, l - \bar{H}i*\right) \left(Hj, l - \bar{H}_{j*}\right) \tag{5}$$

The authors also include a figure comparing six signal examples from three people diagnosed with PD and three healthy controls. The figure demonstrates the normalized flight time series (NFT) split into 15-second-length windows and the application of Kernel Density Estimation (KDE) to compute the sub-distribution representing the information contained in each window. Four features σ_{Kt} are included in the final 7-dimensional feature vector, and three metrics are extracted from the covariance analysis.

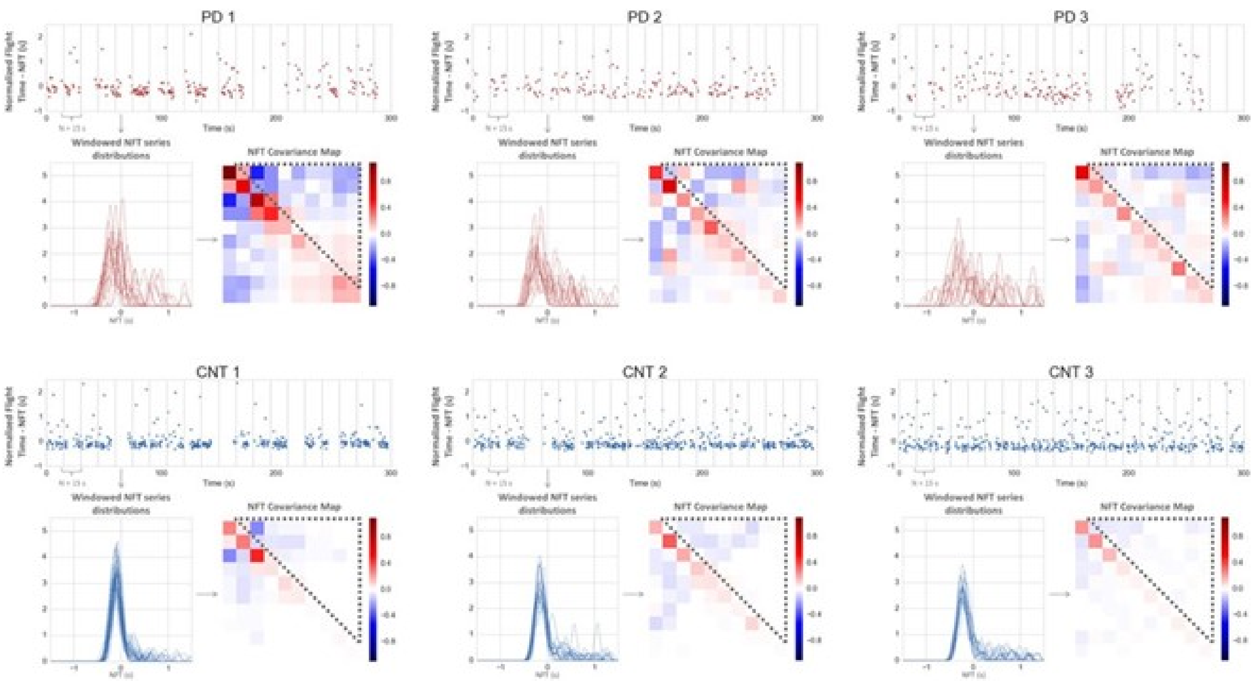

Figure 2: Normalized flight time series (NFT) and Kernel Density Estimation (KDE) computed sub-distributions from three Parkinson's patients and three healthy controls. The figure also shows the covariance maps for both groups. Adapted from [16].

The figure illustrates that the mean and standard deviation of skewness and kurtosis values measured on each sub-distribution define four features σ_{Kt} in the final 7-dimensional feature vector. The NFT covariance map represents the correlation across the NFT sub-distributions. The covariance vector (Cv) is an array that includes the coefficients in the strict upper triangle of the covariance matrix, i.e., above the matrix's main diagonal. The authors extract three metrics from the covariance analysis that complete the typing feature vector $\sum |Cv|$. The figure shows that distributions have higher uniformity of NFT values for healthy control subjects than for Parkinson's patients. Covariance maps for PD patients demonstrate stronger correlation and anti-correlation within sub-distributions, while healthy control subjects' maps present values closer to 0 for the entire matrix [16].

The analysis of typing signals using data acquisition and analysis methods presented by Arroyo-Gallego et al. [16] has the potential to detect motor impairments in Parkinson's disease via mobile touchscreen typing. The study's methodology provides a foundation for future research. At the same time, the detailed data analysis methods, including signal conditioning, feature extraction, and statistical techniques, can be applied to other datasets related to motor impairments or different medical conditions. Including the figure from the article in your work will help visually explain the differences in NFT distributions and covariance maps between Parkinson's patients and healthy controls, highlighting the potential of this approach for detecting PD status.

7 Future Works

The current article explores the ongoing research on utilizing touchscreen technology for the analysis and prediction of neurological disorders, specifically focusing on Parkinson's disease. While providing a comprehensive overview of the state of the field, the limitations and challenges of existing research have been critically examined.

Building on the knowledge gained from this review, the author plans to embark on a research project over the summer of 2023 to develop a custom web browser application or web app designed to generate touch data from user interactions. This application will present users with various tasks and continuously monitor their touch input, generating valuable data for further analysis.

Initially, off-the-shelf models and algorithms will train a machine-learning model using the collected data. As the project progresses and the findings accumulate, the author may opt to customize or refine the model to improve its accuracy and efficacy in detecting Parkinson's disease and potentially other neurological disorders.

The proposed research addresses the limitations and shortcomings identified in the current article. In addition, it contributes to the ongoing efforts to develop non-invasive, accessible, and innovative diagnostic tools for neurological disorders. By creating a custom web app and experimenting with various machine learning algorithms, this project aims to push the boundaries of what is possible in the field and ultimately improve the lives of those affected by these debilitating conditions.

The findings and outcomes of this research project will be documented and shared in a follow-up article detailing the development process, challenges faced, and insights gained. Stay tuned for updates on this exciting endeavour as the author strives to contribute to the growing body of knowledge in touchscreen technology and its applications in neurological disorder detection and monitoring.

References

[1] M. Hossain, M. Islam, A. Adhikary, A. Rahaman, and M. Z. Islam, “Bioinformatics approach to identify significant biomarkers, drug targets shared between parkinson’s disease and bipolar disorder: A pilot study,” *Bioinformatics and Biology Insights*, vol. 16, pp. 1–9, 02 2022.

[2] B. Shen, L. Yuxin, C. Bi, S. Zhou, Z. Bai, G. Zheng, and J. Zhou, “Translational informatics for parkinson’s disease: from big biomedical data to small actionable alterations,” *Genomics, Proteomics & Bioinformatics*, vol. 17, 11 2019.

[3] R. A. M. D. Simeoli R, Milano N, “Using technology to identify children with autism through motor abnormalities,” *Front Psychol*, vol. 12, p. 635696, 2021.

[4] W. Li, J. Guo, J. Chen, H. Yao, R. Mao, C. Li, G. Zhang, Z. Chen, X. Xu, and C. Wang, “Identification of immune infiltration and the potential biomarkers in diabetic peripheral neuropathy through bioinformatics and machine learning methods,” *Biomolecules*, vol. 13, no. 1, 2023. [Online]. Available: https://www.mdpi.com/2218-273X/13/1/39

[5] M. Damasceno and A. M. P. Canuto, “An empirical analysis of ensemble systems in cancellable behavioural biometrics: A touch screen dataset,” pp. 2661–2668, 2014.

[6] M. B. Broschard, J. Kim, B. C. Love, and J. H. Freeman, “Category learning in rodents using touchscreen-based tasks,” *Genes, Brain and Behavior*, vol. 20, no. 1, p. e12665, 2021. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/gbb.12665

[7] E. C. M. T. Ivonne Monarca, Franceli L. Cibrian, “Using a small dataset to classify strength-interactions with an elastic display: A case study for the screening of autism spectrum disorder,” *International Journal of Machine Learning and Cybernetics*, vol. 14, pp. 151–169, 2022.

[8] E. Billing, T. Belpaeme, H. Cai, H.-L. Cao, A. Ciocan, C. Costescu, D. David, R. Homewood, D. Hernandez Garcia, P. Gómez Esteban, H. Liu, V. Nair, S. Matu, A. Mazel, M. Selescu, E. Senft, S. Thill, B. Vanderborght, D. Vernon, and T. Ziemke, “The dream dataset: Supporting a data-driven study of autism spectrum disorder and robot enhanced therapy,” *PLOS ONE*, vol. 15, no. 8, pp. 1–15, 08 2020. [Online]. Available: https://doi.org/10.1371/journal.pone.0236939

[9] C. J. Heath, C. O’Callaghan, S. L. Mason, B. U. Phillips, L. M. Saksida, T. W. Robbins, R. A. Barker, T. J. Bussey, and B. J. Sahakian, “A touchscreen motivation assessment evaluated in huntington’s disease patients and r6/1 model mice,” *Frontiers in Neurology*, vol. 10, 2019. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fneur.2019.00858

[10] S. Valladares-Rodriguez, M. J. Fernández-Iglesias, L. Anido-Rifón, D. Facal, C. Rivas-Costa, and R. Pérez-Rodríguez, “Touchscreen games to detect cognitive impairment in senior adults. a user-interaction pilot study,” *International Journal of Medical Informatics*, vol. 127, pp. 52–62, 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1386505618301631

[11] F. Giaquinto, P. Battista, and P. Angelelli, “Touchscreen cognitive tools for mild cognitive impairment and dementia used in primary care across diverse cultural and literacy populations: A systematic review,” *Journal of Alzheimer’s disease: JAD*, 10 2022.

[12] D. Iakovakis, S. Hadjidimitriou, V. Charisis, S. Bostantzopoulou, Z. Katsarou, and L. Hadjileontiadis, "Touchscreen typing-pattern analysis for detecting fine motor skills decline in early-stage parkinson's disease," *Scientific Reports*, vol. 8, 05 2018.

[13] N. Pitchford and L. Outhwaite, "Can touch screen tablets be used to assess cognitive and motor skills in early years primary school children? a cross-cultural study," *Frontiers in Psychology*, vol. 7, 10 2016.

[14] J. Weyhenmeyer, M. E. Hernandez, C. Lainscsek, H. Poizner, and T. J. Sejnowski, "Multimodal classification of parkinson's disease using differential delay analysis," pp. 2868–2875, 2020.

[15] A. Mathur, R. K. Dwivedi, and R. Rastogi, "A survey of machine learning based approaches for neurological disorders predictions," pp. 586–590, 2022.

[16] T. Arroyo-Gallego, M. J. Ledesma-Carbayo, Sánchez-Ferro, I. Butterworth, C. S. Mendoza, M. Matarazzo, P. Montero, R. López-Blanco, V. Puertas-Martín, R. Trincado, and L. Giancardo, "Detection of motor impairment in parkinson's disease via mobile touchscreen typing," pp. 1994–2002, 2017.