Proposal: An AI-Driven Early Detection and Monitoring System for Neurodegenerative Diseases

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Abstract

Neurodegenerative diseases progress slowly and silently, often taking years before diagnosis is made in a clinical setting. By the time symptoms such as memory loss, motor decline, or speech disruption are recognized, irreversible damage has already occurred. This paper proposes the design of a smartphone-based system that can capture subtle changes in speech, motor performance, and cognitive processing, translating them into a consolidated Neuro Score. The Neuro Score offers a simple, continuous measure of neurological stability or decline, allowing physicians and patients to track shifts in health across time. This system is not intended to replace diagnostic testing but rather to serve as a monitoring and support tool, providing physicians with actionable context and individuals with the reassurance of continuous oversight. We describe the scientific foundations, methods, and use cases of the proposed system, illustrate how it functions through sample patient narratives, and outline future steps required to validate and expand its capabilities.

Introduction

Traditional methods of detecting diseases like Parkinson's, Alzheimer's, ALS, and Mild Cognitive Impairment rely on costly imaging, invasive fluid tests, or late-stage symptomatic evaluation. PET scans that reveal amyloid plaques, cerebrospinal fluid analysis that uncovers abnormal tau or alpha-synuclein proteins, and EEG recordings that detect disrupted rhythms are all scientifically robust, but they remain inaccessible for continuous or preventative care. For families, diagnosis often arrives only after years of unnoticed decline, leaving little room for early intervention.

This proposal describes a system that instead uses everyday tools—smartphones—to generate continuous streams of behavioral and cognitive data. By leveraging advances in AI analysis of voice, tapping rhythms, walking pace, and memory recall, the system constructs a personal baseline and identifies even the smallest deviations from it. These deviations are then transformed into a Neuro Score, a number that reflects risk of disease progression. Importantly, this proposal emphasizes that the system is a **monitoring and early warning tool**, not a diagnostic substitute. Its purpose is to augment doctor-patient communication and to create an early safety net, similar to how wearable heart monitors detect arrhythmias before a cardiac event.

Methods

Speech and Language Analysis

Speech is a complex behavior that depends on precise coordination of neural circuits across multiple brain regions. Neurodegenerative diseases frequently disturb this system in

predictable ways. In Parkinson's disease, for instance, patients often lose vocal volume, producing a soft monotone voice. ALS patients display slurred or labored articulation as motor neurons fail, while Alzheimer's patients struggle with word retrieval, vagueness of expression, and errors in sentence construction. The proposed system incorporates a regular speech task in which patients read aloud simple phrases into their smartphones. These recordings are not judged on comprehension but analyzed acoustically and linguistically.

The system measures pitch variability, detecting whether the voice has lost melodic quality. It calculates the rhythm of speech, identifying hesitations or interruptions in flow. It analyzes articulation clarity by isolating consonant sounds such as "p," "t," and "k," which demand crisp execution. It also examines lexical retrieval, flagging the frequency of pauses or circumlocutions such as "the thing you use to tell time" instead of "watch." These linguistic changes, though imperceptible in casual conversation, become clear through quantitative tracking. By comparing new recordings to a patient's personal baseline, the system identifies shifts that may represent the earliest onset of neurodegenerative disruption.

Motor and Gait Tracking

Motor control is another domain where disease manifests subtly before becoming clinically obvious. The system employs two smartphone-based tasks: a tapping test and a walking test. The tapping test requires the patient to tap the screen as quickly and consistently as possible, measuring steadiness, rhythm, and fatigue. This allows the AI to capture tremor irregularities or slowed response times. The walking test, conducted with the phone in the pocket, records stride length, cadence, and variability using built-in accelerometers. Even small increases in double-support time, when both feet are on the ground, can indicate cognitive-motor integration loss, which is an early symptom of Mild Cognitive Impairment.

Rather than seeking absolute thresholds, the system establishes a patient's baseline during the first two weeks of use. For example, if a person's natural stride length is 70 centimeters and it decreases gradually by 12 percent over eight months, the system flags this as a meaningful change, even though the new stride length might still fall within "normal" population ranges. This individualized approach prevents false alarms while ensuring that subtle but progressive shifts are not ignored.

Memory and Cognitive Testing

Cognitive impairment is most often detected through lengthy neuropsychological testing in clinical settings, but early signs can be captured through lightweight digital tasks. The system includes short memory games where patients recall sequences of words or patterns. These tests measure both immediate recall and delayed retrieval, which are sensitive markers of decline. For example, an increase in hesitation before recalling a simple word list or a doubling in pause length during narrative speech can suggest early Alzheimer's progression.

The system is not designed to test whether the patient can "pass" or "fail" but to measure the consistency of performance relative to the individual's own baseline. If a patient who typically recalls five out of five words begins to consistently recall only three or four, even without subjective awareness, the AI captures this downward drift. Combined with speech and motor metrics, these cognitive data points strengthen the reliability of the overall Neuro Score.

The Neuro Score

The Neuro Score serves as the unifying indicator of neurological health. Rather than overwhelming patients and physicians with dozens of raw metrics, the score condenses changes in speech clarity, motor steadiness, walking pace, and memory recall into a single value between 0 and 100. A stable score near zero suggests no meaningful change, while rising scores indicate risk that may warrant attention. Importantly, the score is not arbitrary: it is computed by weighting percent deviations in each domain against the baseline and summing the results.

For instance, if a patient's speech clarity drops by 20 percent, hand steadiness declines by 15 percent, and walking pace slows by 10 percent, each deviation contributes proportionally to the Neuro Score. The score thus reflects cumulative burden across multiple systems. What makes this proposal distinctive is not the number itself, but the trend over time. A single elevated score may reflect fatigue or stress, but a steadily rising trajectory reveals a deeper neurological pattern that should be investigated.

Sample Application in Patients

The system is best understood through practical examples. Consider Maria, whose baseline indicated perfect clarity in speech and normal walking pace. After three months, her speech became 20 percent less clear and her walking slowed by 15 percent. Her Neuro Score rose to 35, a significant change. When viewed by her neurologist, this pointed to deterioration consistent with early Parkinson's and justified closer monitoring. In another case, Susan's hand steadiness and walking speed remained intact, but her word-finding pauses in speech doubled from 0.8 seconds to 1.6 seconds. Although her Neuro Score remained low, the detailed narrative flagged early cognitive disruption that could be linked to Alzheimer's. This demonstrates how the system not only produces a score but contextualizes nuanced observations for physician review.

David presented a more alarming case, where speech clarity fell 35 percent, steadiness by 20 percent, and gait speed by 25 percent within two months. His Neuro Score reached 60, revealing rapid multi-system decline characteristic of ALS. Such a profile would alert clinicians to the urgency of evaluation. These narratives exemplify the system's potential: it transforms scattered, subtle symptoms into a structured, comprehensible report that enables earlier, better-informed decisions.

Ethical and Privacy Considerations

The collection of sensitive neurological data requires strict ethical safeguards. The system is designed so that no personally identifying information, such as names or phone numbers, is stored. Instead, patients are assigned randomized identifiers. All data is encrypted during transmission and storage, and servers comply with HIPAA and GDPR standards. Patients retain full control over their information, with the ability to delete their accounts and data permanently or to selectively share reports with physicians or family. The system emphasizes in all consent materials that it is not a diagnostic device but a monitoring tool, reducing the risk of misinterpretation or overreliance. This balance between innovation and patient autonomy is essential for adoption and trust.

Discussion

The proposal reflects a paradigm shift from episodic, clinic-based assessments to continuous, patient-centered monitoring. By embedding health checks into daily life, the system identifies subtle declines that would otherwise remain invisible until too late. The Neuro Score and accompanying dashboards offer both simplicity and depth: a headline number for easy interpretation and detailed narratives for nuanced clinical judgment.

Research applications are equally promising. With user consent and anonymization, aggregated datasets could reveal new digital biomarkers, allowing scientists to study how changes in tapping rhythm or word retrieval predict disease years before diagnosis. At the same time, the system democratizes access to neurological monitoring, reducing reliance on expensive imaging or invasive fluid tests. However, the approach is not without limitations. Variability due to fatigue, stress, or environment may influence results, and validation against gold-standard clinical metrics remains a critical next step.

Conclusion

This paper has proposed a smartphone-based monitoring system that consolidates speech, motor, and cognitive data into a Neuro Score, producing a powerful early-warning signal for neurodegenerative diseases. The system is built not to diagnose, but to empower: to provide patients with transparency about their neurological health and to furnish physicians with structured, objective data to guide care. The sample patient narratives demonstrate how the system captures change, contextualizes findings, and bridges the gap between subtle symptoms and actionable insight.

The significance of this proposal lies in its reimagining of brain health monitoring. Instead of waiting for catastrophic symptoms, individuals could track their neurological well-being as routinely as they track their steps or heart rate. Physicians could use the data to anticipate decline, adjust therapies, or order confirmatory testing at the earliest possible stage. Researchers could use the anonymized datasets to push forward the science of digital biomarkers.

Future steps will focus on validating the Neuro Score against established clinical tests, integrating advanced biomarkers such as EEG and eye-tracking, and refining the predictive power of the AI models. If successful, the system could become a silent but reliable alarm for the brain, alerting us to hidden decline before it becomes irreversible. In doing so, it has the potential to transform neurodegenerative care from reactive treatment to proactive prevention, fundamentally shifting how we understand and protect the most vital organ of human life.

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