Implementatie van spraakbiomarkers in het digitaal gezondheidsplatform NeuroPath voor personen met de ziekte van Parkinson

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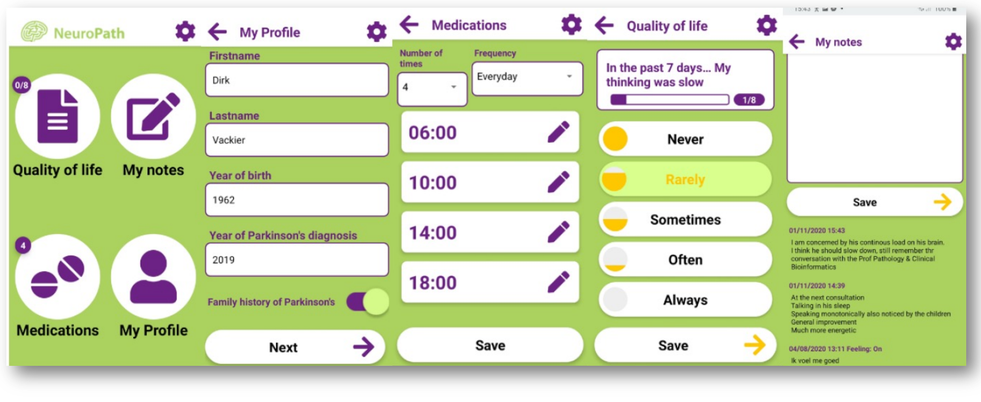
ACHTERGROND EN VERWACHT EINDPRODUCT

Binnen het **project NeuroInsights** wordt een digitaal multidisciplinair gezondheidsplatform ontwikkeld om het ziekteverloop van personen met de ziekte van Parkinson beter te monitoren, onder leiding van NeuroPath.
Dit platform draait op **laagdrempelige dataverzameling** via mobiele toestellen (vb. smartphone en wearables) en voorziet een **grafische gebruikersinterface** (vb. spindiagram) met praktische aanbevelingen voor de zorgverlener.

- Opvolgen van motorische symptomen: **markerless motion capturing** (MoCap) systeem voor thuismonitoring van beweeglijkheid
- Opvolgen van niet-motorische symptomen: **wearables** (aantal stappen, slaapkwaliteit, bloeddruk, …), **vragenlijsten** (depressie, QoL, …)
- Intelligente spraakassistent (**chat bot**): om medische protocollen (vb. UPDRS) en vragenlijsten (vb. NeuroQoL) te doorlopen
- **STEM EN SPRAAK: capteren van spraak en extraheren van relevante biomarkers + module voor spraakoefeningen (evidence-based protocol)**



BIOMARKERS

Rol van artificiële intelligentie in detectie en progressie van Parkinson via stem en spraak

- (Differentiaal) diagnostisch toepassen
- Progressie ziekte beter voorspellen
- Finetunen van timing overstap naar andere behandeling
- Neuroloog ondersteunen bij doorverwijzing naar logopedie

- **State-of-the-art biomarkers stem en spraak**
- **Gestandaardiseerd protocol met spreektaken (NL, FR, ENG)**

- Via **algoritmes** bepalen van **trends/patronen in spraakstalen**

FINAL SELECTION of acoustic measures for the NeuroPath speech analysis

MANDATORY SPEECH TASKS
Conversational speech (and reading), vowel prolongation, diadochokinesis (AMR).

VOICE
Emerging evidence suggests that ***voice dysfunction is the earliest sign of motor impairment in PD***.
Voice tremor in the range of 4-7 Hz has been reported in some speakers with PD, but it is not pervasively present perceptually or acoustically and is therefore ***not essential for a diagnosis of hypokinetic dysarthria***.
Note Annelies: Implement the Tremor Protocol to detect true laryngeal tremor in later stages of the disease?

- *Reduced* ***harmonics-to-noise ratio (HNR)***, correlating with a rough and hoarse voice.
- *Increases in* ***jitter***, with further increases as the disease progresses, is associated with a rough and creaky vocal quality.
- *Increases in* ***shimmer*** are associated with breathiness during steady phonation.
- ***Higher mean fundamental frequency*** (f_0) associated with elevated pitch.
- ***Reduced f_0 and intensity variation or range***, associated with reduced contrastivity.
  - In this, the measure ***Pitch Period Entropy (PPE)*** might be of interest to reduce confounding effects due to noisy acoustic environments.
- Transitions from vowels to consonants may be voiceless → ***gaping in-between voiced speech (GVI)***.
- Continuous voicing within utterances containing voiceless consonants → ***mean duration of voiced intervals (DVI)***.
- *Declines in maximum and average duration of sustained vowel prolongations* (MPT) > sensitive to changes over time (see also "respiration").
- *Reduced vocal intensity and declines in intensity across syllables*, reflecting hypophonia.
- *Long-term average spectrum (LTAS)* > shape of the energy distribution in the acoustic spectrum.
- ***The Voice and Tremor Protocol (VTP)*** *> the rate, periodicity, and magnitude of frequency and amplitude tremor*

ARTICULATION

- ***Spirantization*** during stop and affricate productions → reduces acoustic contrast and detail.
  - Performance of the most challenging articulatory movements represented by stop consonants was directly measured by the **duration of unvoiced stops (DUS)**.
- Reduced range and speed of articulator movement:
  - *Reduced formant transitions* (F2 range)
  - *Reduced F2 slope* (rate of formant change)
  - ***Restricted acoustic vowel space***
  - ***Formant centralization ratio*** = metric for indexing restricted vowel space (centralization of vowels) → sensitive to gains derived from speech therapy.
- ***Increased or accelerated rate*** on speech AMR and meaningful connected speech tasks.
- Kinetic behaviour of the ***envelope trace of the DDK AMR tasks*** (/papapa/, /tatata/, /kakaka/) .

- *Dysfluencies* → repeated or prolonged phonemes, at the beginning of utterances or following pauses, sometimes rapid or blurred and restricted in ROM. May sound more like a prolonged vowel or consonant with a tremulous character (analogous to "freezing" during walking).
- *Palilalia* → compulsive reiteration of utterances in a context of increasing rate and decreasing loudness, usually involves words and phrases
- *Both are associated with more advanced stages of PD (Benke et al., 2000)!*

PROSODY

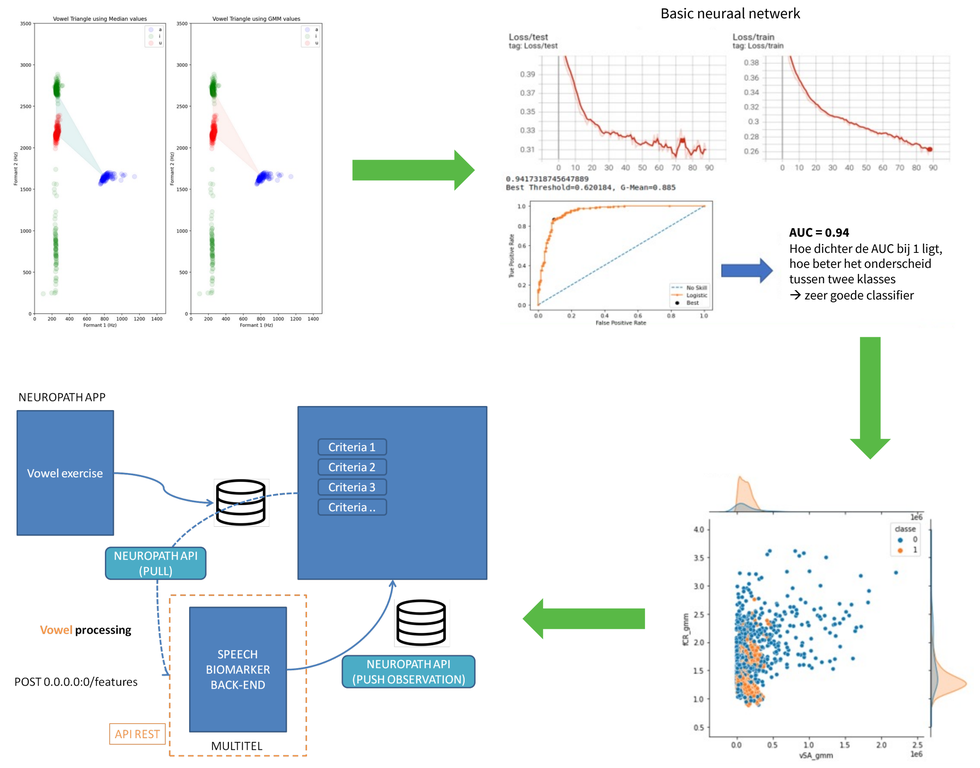
- Silent pauses:
  - *More frequent* silent pauses.
  - *Increased duration* of silent pauses.
  - *Higher percentage* silent pauses of the total time within speech samples.
- Perception of short rushes of speech:
  - *Hesitations or pauses more frequently at the beginning of utterances.*
  - *Increased number of words between silent intervals.*
- Speech rate with respect to quality of speech timing as the **rate of speech timing (RST)** including voiced, unvoiced and pause intervals.
- **Duration of pause intervals (DPI)** can be heavily influenced by the ability to properly initiate speech.
- Acceleration of speech computed by **acceleration of speech timing (AST)** including voiced, unvoiced and pause intervals = extent of timing acceleration.
- Perception of reduced stress:
  - Reduced differences in word boundary durations between separate nouns and compound nouns, e.g., "sailboats" versus "they will sail boats".
- *Rhythm metrics or envelope modulation spectra* can distinguish hypokinetic dysarthria from normal speech → perceptual characterization as rapid or rushed.
- ***Reduced variation of intensity*** → monoloudness.
- ***Decrease in the variability of fundamental frequency*** → monopitch.
  - Reduced ability to mark syntactic boundaries with appropriate pitch contours.

RESPIRATION

- *Reduced maximum vowel duration* (MPT).
- *Rate of speech respiration (RSR)* → estimates respiratory rate during speech.
- Fewer syllables per speech group → *pause intervals per respiration (PIR).*
- Increased breath groups during reading (correlation with shorter utterance length) → *pause intervals per respiration (PIR).*
- Problems in coordinating language planning with respiratory support

VOORBEELD ARTICULATIE

- Bepalen van **KLINKERDRIEHOEK**: F1-F2 configuratie van vocalen /a/, /i/ en /u/ → akoestisch correlaat van positionering van articulatoren → wordt kleiner naarmate hypokinesie toeneemt bij personen met Parkinson
- **Voorbeelden** zijn vowel space area (VSA), formant centralization ratio (FCR) en voice articulation index (VAI)
- **Basic neuraal netwerk** leert het onderscheid tussen Parkinson/niet-Parkinson → preliminair resultaat toont een **goede classifier**
- **REST API** in een kant-en-klare docker container **extraheert** dit akoestisch correlaat uit een spraakstaal opgeslagen in de NeuroPath app
- In de back-end wordt deze biomarker verwerkt en vervolgens **terug gepusht als waarneming** naar de Neuropath app (vb. in spindiagram)



Hlavnička, J., Čmejla, R., Tykalová, T., Šonka, K., Růžička, E., & Rusz, J. (2017). Automated analysis of connected speech reveals early biomarkers of Parkinson's disease in patients with rapid eye movement sleep behaviour disorder. *Scientific reports, 7*(1), 1-13.

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