Team Results Document

TUcanSense



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SensUs

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Parkinson's disease

1 Abstract

Parkinson’s disease (PD) patients undergoing levodopa (LD) therapy often experience unpredictable ON-OFF fluctuations and dyskinesia as the disease progresses. Current treatment optimization remains challenging, as neurologists primarily rely on clinical observations and subjective patient reports rather than objective measurements of LD exposure. This uncertainty undermines both patients' and neurologists' confidence in treatment decisions. Interviews highlighted the lack of objective LD data as a major challenge in PD management, especially for patients with a narrow therapeutic window who require increasingly precise LD therapy optimization.

TUcanSense addresses this gap with a wearable biosensor that continuously measures LD concentration in interstitial fluid (ISF) using a minimally invasive microneedle patch. A molecularly imprinted polymer selectively captures LD, and an electrochemical readout converts this interaction into a measurable signal.

Continuous levodopa monitoring provides neurologists with objective insights into individual levodopa fluctuations and pharmacokinetic profiles, supporting personalized dose adjustments. For patients with a narrow therapeutic window, this enables improved disease management with the potential to enhance quality of life and support better long-term clinical outcomes. The translational pathway starts with specialised PD clinics for clinical validation and expert adoption, followed by expansion into broader neurological care.

2 AP award: Biosensor developed for the Eindhoven Testing Event

2.1 Molecular recognition

LD is captured and quantified in ISF using a molecularly imprinted polymer (MIP) as the sensing element (Zhou et al., 2025). The MIP layer, which consists of pyrrole with resorcinol as co-monomer, is synthesized directly on the screen-printed carbon working electrode by electropolymerization under cyclic voltammetry. After synthesis, LD is washed out, leaving specific and high affinity cavities behind (Pourhajghanbar et al., 2022; Sooraj et al., 2020).Gold nanoparticles (AuNP) are deposited on the working electrode by electrochemical reduction of $HAuCl_4$, enhancing the surface area and electron transfer. A Nafion coating is applied to minimize interference from electroactive species commonly present in biological fluids, particularly ascorbic acid and uric acid. During detection, LD binds to the imprinted cavities. Differential Pulse Voltammetry (DPV) is then applied, oxidizing it to L-Dopaquinone which generates a peak current proportional to the LD concentration (Sooraj et al., 2020, Zhou et al., 2025).

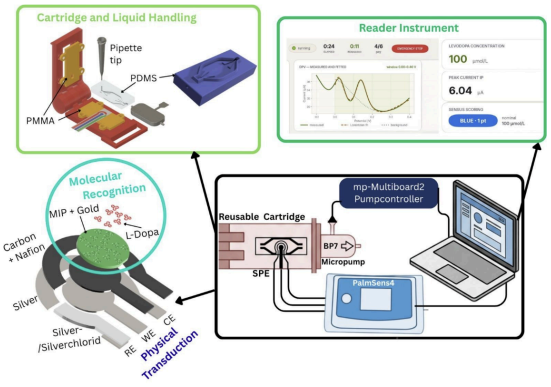


Figure 1: Overview of the Sensor Principle

2.2 Physical transduction

DPV was chosen as the transduction method because it ranks among the most sensitive voltammetric techniques for concentration determination, as it suppresses background contributions such as interfacial capacitance charging far more effectively than simpler alternatives (Bard et al., 2001). Binding of LD to the MIP produces a redox reaction at the working electrode, seen as a rise in peak current under DPV (Zhou et al., 2025); this signal is processed downstream to yield a concentration value (section 2.4).

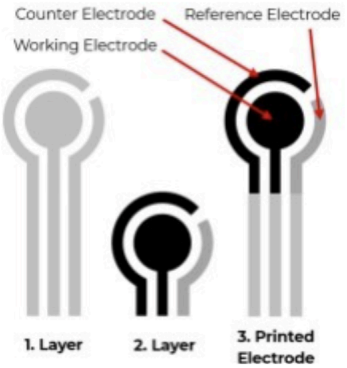


Figure 2: Screen Printed Carbon Electrode

The sensor itself is a three-electrode system: working electrode (WE), counter electrode (CE), and reference

electrode (RE), fabricated in two printed layers . A silver base layer reduces electrical resistance across each electrode. On top of this, the WE and CE are printed with carbon ink, chosen for its low cost and low background current across a wide potential window relative to metal electrodes (Gornall et al., 2009). The RE consists of silver/silver chloride.

2.3 Cartridge technology & Reader instrument

The cartridge is designed to be reusable with interchangeable electrodes. It is composed of a PDMS channel, a PMMA top and bottom, a pipette based inlet and a micro pump outlet. We model our system after (Fechner et al., 2024) and (Lapp, 2025). The PDMS has the channel structure engraved and a 1mm rim around the channel. By applying just enough surface pressure to completely collapse the rim, the electrode is firmly held in place and the channel is sealed. In order to minimize the volume while also keeping optimal flow conditions, the in- and outlet is split into 3 parts each with an opening angle of 16 degrees (Nafea et al., 2019) which come together in the sensing area. Readout is performed on a PalmSens 4 potentiostat. Fluid handling uses Bartels BP7 piezoelectric micropump.

2.4 Operating software

Both instruments are controlled through a single in-house application, TUcanSense Fluidcontrol, running locally on the operator's laptop with a browser-based interface. The interface covers five functions: manual control, protocol building, flow calibration, analysis, and device connection (Figure 4, Appendix L). During execution the operator can monitor progress and abort the measurement at any point. The analysis view overlays the fitted peak on the raw curve, so a poor fit is visible rather than absorbed into a single number. Protocols are validated before execution rather than during: the software checks upfront whether the fluidic window is long enough for the selected scan, and all pumps shut off unconditionally at the end of a run, whether it completes, is aborted, or errors out.

3 IN award: Biosensor innovation

3.1. Wearable sensor

3.1.1. Technological novelty of wearable sensor

We propose a compact, skin-worn patch for continuous LD monitoring in ISF. The device is a modular sensing platform adapted from the architecture of continuous glucose monitoring (CGM) systems, particularly Dexcom's platform, for continuous LD measurement. A hollow microneedle array penetrates the outer skin barrier to access ISF (Li et al., 2019). Extracted fluid flows passively through a hydrophilic microfluidic pathway from a collection chamber into a downstream sensing chamber before entering a porous absorber that provides the capillary force for transport, eliminating the need for a mechanical micropump (Samant & Prausnitz, 2018).

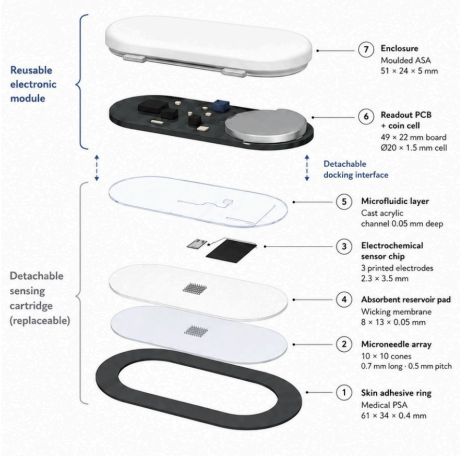


Figure 3: Proposed model of the Sensor

Within the sensing chamber, ISF passes over an integrated three-electrode cell. The working electrode contains the LD-selective MIP layer described in the AP Award section. A miniaturized potentiostat records the signal, which is processed by a microcontroller and transmitted via Bluetooth to a mobile application.

The novelty lies in the modular architecture rather than the individual sensing components. Only the MIP-functionalized working electrode and disposable skin-contacting patch are newly developed, while the transducer electronics and applicator remain compatible with an established commercial CGM platform through the adoption of passive ISF extraction, microneedle-based sampling, and an exchangeable transducer design (Dexcom, Inc., 2013, 2020, 2021a, 2021b).

Positioning the microneedle outlets upstream of the planar sensor allows freshly extracted ISF to flow through a small sensing chamber, minimizing sample mixing while preserving temporal resolution. This modular design is also expected to provide economic and regulatory advantages over a fully independent sensor system (Section 3.1.2).

3.1.2. Technical feasibility of wearable sensor

The key functions required for the proposed wearable system: microneedle-based ISF sampling, electrochemical LD detection, and microfluidic integration have each been demonstrated experimentally. A hollow microneedle array provides minimally invasive access to ISF (Li et al., 2019). Extracted fluid is transported passively through a hydrophilic microfluidic channel into a downstream sensing chamber by capillary action generated by a porous absorber, eliminating the need for a mechanical micropump (Samant & Prausnitz, 2018).

Our concept combines these established technologies with our printed LD sensor to enable passive microfluidic sampling for continuous electrochemical monitoring. While the complete device has not yet been manufactured or validated in vivo, its mechanical and fluidic architecture follows commercially established CGM systems that have demonstrated reliable long-term clinical performance (Heinemann, 2018). Together, the published demonstrations of hollow microneedle sampling (Li et al., 2019), wearable LD detection (Goud et al., 2019), and microneedle–microfluidic integration (Parrilla et al., 2022) support the technical feasibility of the proposed system.

Beyond technical feasibility, the modular design is expected to reduce manufacturing and regulatory barriers. Although adapting an existing automated production process requires retooling and equipment modifications, these costs are substantially lower than establishing an entirely new production line because existing manufacturing steps and equipment can be retained (Albus, 2025). By developing only the electrode and disposable skin patch while reusing the transducer and applicator of an established glucose sensor platform, the proposed design is expected to reduce development costs, regulatory burden, and time to clinical implementation.

Future work will validate passive fluid transport, cartridge sealing, repeated-measurement performance, long-term skin attachment, and the mechanical and electrical compatibility of the sensing cartridge with a commercial glucose sensor transducer and applicator.

3.2. Reliability of sensor output

3.2.1. Sensor Level Reliability

Reliable LD monitoring is mainly limited by electrode fouling and electrochemical interference. Oxidation products of LD, including dopaquinone, DHICA and 5,6-dihydroxyindole, can accumulate on the electrode and form eumelanin. Proteins such as albumin and globulin may further block the surface. Interferences including uric acid and ascorbic acid can also affect the signal because their oxidation potentials are close to that of LD. The MIP described in the AP Award section provides selective recognition of LD and helps distinguish it from structurally different compounds.

To improve long term stability, we propose a Nafion and AuNP layer beneath the MIP. The negatively charged Nafion layer reduces the access of anionic interferents through Donnan exclusion and limits fouling by proteins and other unwanted compounds. However, Nafion may also reduce electron transfer and sensor sensitivity. The AuNP interlayer compensates for this limitation by improving electron transfer and increasing the electrochemically active surface area. AuNP modification has been reported to increase the active area by approximately two to five times, which can help offset signal loss caused by the Nafion layer (Jiang et al., 2018). Together the MIP, Nafion and AuNP layers provide selective recognition, reduced interference and improved signal stability. The effectiveness of the complete stack still requires experimental validation in real ISF.

3.2.2. Cartridge Level Reliability

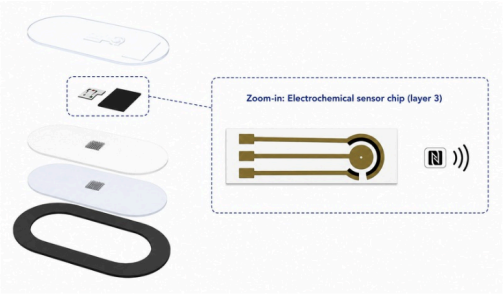


Figure 4: Enlarged view of the electrochemical sensor within the detachable sensing cartridge.Each cartridge carries an NFC enabled DCI for cartridge specific calibration

The detachable cartridge described in Section 3.1 also supports reliable long term operation. The reusable electronics remain in service, while the fluid contacting sensing cartridge can be replaced when its service life is reached or when performance degradation is detected. This separation reflects the different lifetimes of electronic and sensing components. It also improves maintainability and avoids replacing the complete device when only the sensing interface has deteriorated (Fan & Andrew, 2020; Peterson et al., 2024; Wu et al., 2023).

Each cartridge is assigned a unique Digital Calibration Identity (DCI). This identity links the cartridge to its manufacturing information, electrode batch, calibration parameters, baseline characteristics, recommended life time and quality control limits. It may be implemented using Near-Field Communication(NFC), an electrically readable memory element or another compact identifier. After insertion, the system identities the cartridge

and loads its specific calibration data. It then checks the initial baseline, reference electrode response and indicators of fluid arrival, such as electrode wetting or impedance changes. Measurement begins only if these values remain within predefined acceptance limits.

This approach accounts for differences between individually manufactured cartridges instead of assuming identical behaviour. Previous studies on factory calibrated wearable sensors also show the importance of controlling device variability and clearly defining calibration status (M. Wang et al., 2022). The proposed innovation therefore combines replaceable sensing components, digital traceability, cartridge specific calibration and automatic initial verification. Together these functions provide a verified and traceable starting point for continuous LD monitoring.

3.2.3 Measurement Level Reliability

The DCI verifies the cartridge at the beginning of operation. However, this initial check cannot guarantee stable performance throughout continuous monitoring. Baseline drift, reference electrode changes, reduced regeneration efficiency, unstable fluid transport and increasing signal noise may gradually reduce measurement reliability (Fan & Andrew, 2020; M. Wang et al., 2022). We therefore propose a Real-Time Measurement Quality Assessment Framework (MQAF) that adds a validation step between signal acquisition and result reporting. The workflow changes from Measure, then Report to Measure, Validate then Report.

The proposed framework would evaluate four areas: Sensor health, Signal quality, Sampling integrity and recognition layer performance. Relevant indicators include reference electrode stability, baseline drift, signal to noise ratio, calibration validity, regeneration recovery and evidence of successful fluid transport (Søpstad et al., 2018; Tsai et al., 2023; C. Wang et al., 2025; J. Wang, 2008; M. Wang et al., 2022). These parameters have been used in studies of printed reference electrodes, drift corrected biosensors, regeneratable MIP sensors, factory calibrated wearables and wearable microfluidic systems. Their combination into one transparent framework for continuous LD monitoring represents our system level contribution.

The indicators are combined into a Measurement Quality Index. This index does not calculate the LD Concentration. Instead, it determines whether the result is reliable enough to report. Temporary quality problems trigger a repeated measurement or an internal baseline check. Persistent degradation suspends result reporting and signals that the cartridge should be replaced. The cartridge therefore provides a verified starting point, while the quality framework checks whether this reliability is maintained during operation.

3.3. Original contributions

1. Statement Written by the Team

The student team TUcanSense (TU Darmstadt) conceived, designed, and evaluated the wearable biosensor system and its output reliability strategy for SensUs 2026. The project was developed collaboratively from concept to validation. All team members contributed to the ideation and selection of the sensing concept through literature review and design trade-off analyses. Danilo Savić led the CAD design and prototype development, while Pratham Sachin Patil, Amruth Arun Belawadi, and Yingjie Wang refined the technical specifications, reagent integration, and project documentation. The team fabricated the molecularly imprinted polymer-based sensing electrodes, implemented the electrochemical sensing workflow, conducted customer interviews to guide user-centered design, and developed a validation protocol to assess sensor performance against the clinical gold standard.

2. A piece written independently by the team's supervisor

From my perspective as supervisor, the team's most original contribution is the reliability stack for the wearable LD sensor: combining a Nafion base, an AuNP interlayer, and a pyrrole/resorcinol MIP into a single working-electrode architecture. Each of these elements exists individually in prior literature, but the team was the first to integrate all three into one stack purpose-built to counter the fouling and interference that accompany oxidative LD detection, while also solving self-calibration without removing the patch. Equally original is the passive microfluidic design of the wearable itself, routing ISF from monolithic hollow-microneedles through a pump-free chamber to the sensing electrode via capillary action and an evaporatively regenerating absorber, enabling multi-day continuous wear without moving parts. Together, these contributions move LD monitoring from a benchtop assay toward a genuinely wearable, self-referencing platform, and the team grounded each design choice in quantitative feasibility calculations rather than qualitative claims alone.

Supervisor Name: Andreas Blaeser Signature:  Date: 06.08.2026

Team Captain 1 Name: Danilo Savić Signature:  Date: 07.08.2026

Team Captain 2 Name: Antoine Schneider Signature:  Date: 07.08.2026

3.4. Bonus criteria Innovation

During the development of the wearable platform, the team evaluates several alternative design concepts before selecting the final architecture. One of the earliest design decisions concerned the overall system structure. Instead of replacing the complete wearable device after sensor degradation, we separated the long lived electronic module from the disposable sensing cartridge. This architecture not only reduces cost and electronic waste, but also enables cartridge specific calibration through the DCI introduced in Section 3.2.2. Different identification methods, including QR codes and NFC, were considered during the design process. NFC was ultimately preferred because it enables automatic cartridge identification after insertion without requiring optical alignment or user interaction, making it more suitable for routine long term wearable use.

Another important engineering challenge was the long-term stability of the recognition layer. Unlike conventional protein biofouling, continuous LD monitoring also produces oxidation products such as dopaquinone, DHICA and 5,6-dihydroxyindole. These compounds gradually polymerise into eumelanin, which may foul the electrode and block the MIP recognition sites. This motivated our proposed Nafion/AuNP/MIP multilayer design and highlighted the possible need for future regeneration strategies or sacrificial protective layers. We also evaluated alternative concepts, including tyrosinase-based sensing and polymer hollow microneedles made from PLGA or silk. However, enzymes offer limited long-term stability, while reliable hollow polymer microneedles below 100 µm remain less mature than silicon. Therefore, the MIP-based sensor with silicon hollow microneedles was selected as the final design.

Finally, the team recognised that the proposed architecture represents a modular sensing platform rather than a solution limited to LD monitoring. While the disposable sensing cartridge can be redesigned with alternative recognition layers for other therapeutic drugs or biomarkers, the reusable electronic module, NFC enabled Digital Calibration Identity, and Measurement Quality Assessment Framework remain unchanged. This modular approach reduces future development effort and provides a flexible foundation for extending the platform beyond PD to other applications requiring reliable continuous biochemical monitoring.

4 TP award: Translation potential

4.1. Customer interviews

4.1.1. Identification of potential stakeholders

The stakeholder analysis (Manthey, 2024) began by identifying stakeholder roles, including initiator, decision maker, payer, regulator, end user and influencer. The identified stakeholders were: patients, family members, neurologists, therapists (physiotherapists, speech language therapists, occupational, psychological), hospitals, PD clinics, pharmaceutical companies, caregivers (nurses, home caregivers), regulatory bodies, reimbursement decision-makers, cooperation companies, market competitors, suppliers/producers. Their roles on the project were analysed in a stakeholder characterisation (Smith, 2000) (Appendix A) and their importance evaluated using an interest–influence matrix (Grant & Jordan, 2015) (Appendix B). As the current project stage focuses on identifying pain points and solution strategies, potential end users exhibit the highest levels of interest and influence, making them the primary stakeholders selected for interview conduction: (1) PD patients (Appendix C) are key decision makers and will wear the product continuously, making their needs essential. (2) Family members, especially spouses, are involved in medical decisions while supporting daily challenges. (3) Neurologists manage LD dosage and often initiate device use (Appendix D). (4) Therapists (physio, speech and occupational) see patients weekly but struggle to assess symptoms for accurate session planning. (5) PD clinics provide annual two-week inpatient stays for medication optimization and therapy adjustment. They are playing a role in key opinion leadership, are an important contact for the validation study and are a suitable option for market entry.

4.1.2. Interview approach and execution

A multiple-component interview approach was employed with a total number of 16 patients, 11 neurologists (including 3 from PD clinics), 5 therapists and 4 family members (Appendix E): (A) individual one-on-one interviews following the MOM question style (Appendix F) to identify stakeholder problems without leading participants. (B) Meetings with PD self-help groups, providing additional insights from patients and family members, especially through informal interactions about challenges such as mobility, communication or everyday life. (C) German and English online questionnaires (Appendix G) were distributed via QR codes on flyers (Appendix H) in clinics, healthcare facilities, and

at the *Night of Science* event to complement the interview findings. All participants received project information and provided informed consent before recording. Identities were anonymized (e.g. Patient A, Neurologist B). Interview guidelines covered core topics including diagnostic experience, communication gaps, monitoring challenges, and desired sensor features across all stakeholder groups to ensure cross-case compatibility, while stakeholder-specific topics (e.g. medication management for patients, data presentation for clinicians) were added where relevant. Every interview was documented (Anonymized identifier, interviewer, date, questions, summary, quotes, key takeaways), and responses were coded into a codebook to ensure traceability of every requirement to the original interview and question (Appendix I).

4.1.3. Interview results and conclusions

Results from interview formats (A) and (B) are summarized in the Codebook (Appendix I), with responses grouped by topic (e.g. A1, G2). Representative quotes are provided in Appendix J. For neurologists the key finding was the lack of objective data on patients' condition between visits, reported by 86% of neurologists (A1). LD initiation and dose adjustments rely on brief clinical observations, subjective patient reports and physician experience (A2). Likewise, only 27% of patients had ever tracked their symptoms, but all discontinued because they learned to manage them intuitively (B1). Neurologists and caregivers also reported declining accuracy of patients' self-assessment as the disease progresses (D4). When medication and dose adjustments become challenging or new therapies are considered, neurologists can refer patients to specialized PD clinics. More than half of the neurologists (57%) identified unpredictable gastrointestinal LD absorption as a major challenge, especially when the therapeutic window narrows (A5). Heavy side effects and the general burden of PD disease management lead to 27% patients expressing distrust in their medication (G1). Some reduced their dose without consulting a neurologist (B4). The greatest burden, reported by 45% patients, are unpredictable ON–OFF fluctuations affecting both patients and their families (A3, F7). As PD progresses, 100% of interviewed family members have increasingly become caretakers by supporting medication management (D4), doctors appointments, meals, and daily challenges while adapting to patients' physical and behavioural changes. Regarding disease management, 27% patients described burdensome medication schedules requiring alarms and strict meal timing because food affects LD absorption (F4). While 45% of patients preferred a smartphone app to access LD levels (C6), 27% favoured a dedicated device with features for tremor or visual impairment or a combined solution (C5).

4.2. Design of validation study

4.2.1. Selection of the problem

Currently, LD treatment decisions rely on clinical observations of neurologists and patient-reported symptoms. However, variable LD absorption and pharmacokinetics (Leta et al., 2023) make it hard to distinguish insufficient dosing from altered drug availability as causes of poor symptom control. After 5–10 years of LD therapy (Dodel et al., 2001; Rascol et al., 2003) a narrowing therapeutic window causes motor fluctuations, including unpredictable ON/OFF phases and dyskinesia (Kim et al., 2019; Riley & Lang, 1993), that reduce quality of life. The lack of objective data creates a gap between patients' experiences and neurologists' assessments, limiting trust and personalised treatment adjustments.

4.2.2. Conceptual design and use case

The proposed solution is a minimally invasive wearable biosensor that continuously measures LD levels in ISF via a self-adhesive microneedle patch (Section 2 with certified usage training given. As LD levels correlate with symptom severity (Riley & Lang, 1993), continuous monitoring reduces disease management burden for patients and provides objective data for shared decision-making between patients and neurologists. Patients experiencing symptom fluctuations benefit most from personalized medication and disease management, offering the greatest potential for improved long-term outcomes and clinical value for health insurance reimbursement (Dodel et al., 2001). Specialized PD clinics provide direct access to a scalable number of these patients (Appendix K) and serve as ideal early adopters due to their expertise, multidisciplinary structures, and role as innovation centers (see Figure 5). Based on interview results, continuous LD data are provided to patients through a phone app, including trends, OFF-phase and dyskinesia alerts, medication scheduling functions, and dietary guidance. To address PD-related limitations such as tremor or impaired vision (Boege et al., 2024), an alternative dedicated device with a larger screen and physical buttons can be used. The data are transmitted to a software platform, enabling neurologists to access individual LD profiles for objective assessment and personalized dosage adjustments.

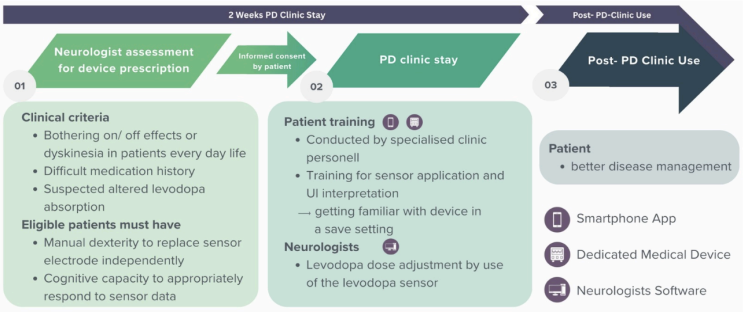
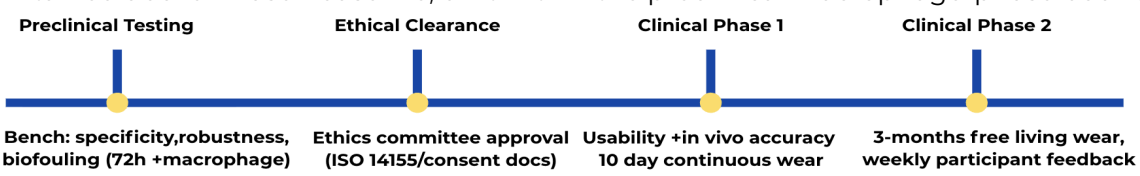


Figure 5: Patient journey with the continuous levodopa sensor during and after the 2 weeks stay in PD clinic

4.2.3. Validation study design

The study has four stages: 1) preclinical testing, 2) ethical clearance, 3) clinical phase I, and 4) clinical phase II, per DIN EN ISO 14155:2020 and IEC 62366-1:2015, targeting stakeholder-raised concerns of attachment, information load, and signal accuracy in real-world wear. 1: Preclinical testing (bench-only, no human samples) covers specificity against ISF interferers (dopamine, ascorbic acid, uric acid, glucose; each <5% of signal). A two-stage biofouling assessment, comprising an early protein/neutrophil phase (first 72h) and a slower macrophage phase (in vitro assay), must clear before on-body testing exceeds 72h (Anderson, 2008). Batch variability and drug-response lag are tested in simulated infusion models, sized by a priori power calculation (α=0.05, power=80%, from pilot bench variance), alongside mechanical/environmental robustness tests (bend, stretch, torsion, vibration, shock, temperature, sweat, motion). 2: Ethical clearance: Protocol and consent materials then go to ethics committee approval under ISO 14155 before enrollment. 3: Clinical studies assess effectiveness for both patients and neurologists. Participants must be able to give informed consent, and be free of skin conditions at the application site and gastrointestinal conditions affecting LD absorption or reference sampling. Usability validation uses 10-15 patients, the point at which 85-95% of usability issues are typically already found (Nielsen & Landauer, 1993). A Wizard-of-Oz test checks correct interpretation of values/trends both on the dedicated-device and the app interfaces. A dummy-skin attachment test with professional training checks correct attachment. Success criteria are: task success ≥90%, no critical errors, system usability scale (SUS) ≥68 (Brooke, 1996; Bangor et al., 2008). A parallel panel of 5-8 neurologists rate the same interfaces for decision confidence and cognitive load (Hart & Staveland, 1988). Technological validation establishes in vivo sensor accuracy in Phase I by comparing sensor measurements with paired venous LD concentrations at clinic checkpoints using Bland–Altman agreement analysis (Bland & Altman, 1986), sample size: α=0.05, power=80%, from preclinical bias variance. Acceptance criterion, adapted from Continuous Glucose Monitoring (CGM) accuracy convention: ≥95% of points within ±15% (or ±15 mg/L below 100 mg/L). Phase I: continuous 10 day wear, checkpoints on days 1-2, 4-7, 10-11, matching CGM regulatory precedent (~10.5 days (Garg et al., 2022)) and the 72h-to-macrophage biofouling transition, continuous wear avoids reapplication variability. Phase II: 3 months free-living wear, weekly comfort rating scale and modified SUS, non-invasive weekly impedance spectroscopy for biofouling drift, and an explant biofouling assay at 3 months as ground truth. It would be considered successful if comfort maintained above Phase 1 baseline, drift within the preclinical macrophage-phase bound.



4.3. Bonus criteria Translation Potential

A comprehensive market analysis was undertaken to define a complementary market entry strategy. Market segmentation (Appendix K) revealed the needs of different end user groups and identified patients with advanced PD experiencing severe LD-induced fluctuations and their treating neurologists as the primary target groups, with PD clinics as our beachhead market. Neurologists also play a vital role in the phased market entry strategy through study conduct, patient access, reimbursement, and product advocacy. To capture perspectives of targeted patients and PD clinic neurologists during further development steps, they have been characterised in personas (Manthey, 2024) (Appendix C, D). Following clinical validation, the first market entry phase will focus on a health economic evaluation to demonstrate the clinical benefit of the sensor when applied by the targeted patients and neurologists compared with current treatment options. Requirements of the identified reimbursement bodies (Appendix A) will be considered. Studies will be conducted in specialized PD clinics and neurological centers. The second phase comprises the product launch in PD clinics (Section 4.2.2), supported by scientific publications, conference presentations and symposia. Product optimization and data collection will guide further market expansion. The third phase focuses on market expansion to patients treated by outpatient neurologists. Current additional opportunities include use by family members, caregivers, and therapists.

The stakeholder analysis (Appendix A) identified potential partners and competitors, including two complementary players to monitor for future competition. Discussions with Pheal, a MedTech startup developing a wearable biosensor platform, identified opportunities for strategic collaboration by combining its platform integration expertise with TUcanSense's electrochemical LD sensor technology. Tooliip, a company developing AI supported PD care solutions, offers complementary expertise in digital patient support and user-centered interfaces. The first funding opportunity will be pursued through participation in the Launch Rhein-Main winter program, a regional startup accelerator.

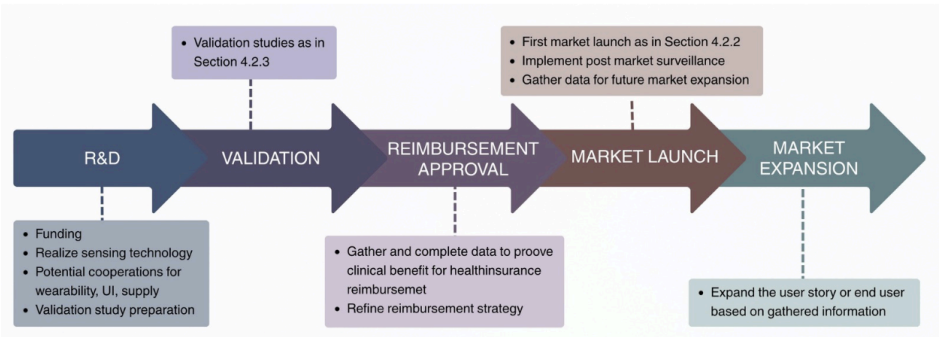


Figure 6: Development and phased market entry stages with related tasks

5 Team and support

5.1. Contributions of the team members

Mohammad Aman: Molecular Recognition, documentation, sponsorship, outreach.
Amruth Arun Belawadi: Molecular Recognition, concept design, documentation, outreach, electrochemical LD sensor.
Antoine Schneider: Business plan, prototyping, sensing-system concept design.
Ajitha Nayac Ravichandiran:Molecular Recognition, prototyping,business plan, documentation.
Danilo Savić: Project management, research integration, concept design, prototyping.
Finn Dante Große-Heilmann: Prototyping, research/reagent integration, sponsorship.
Larissa Arnold: Prototyping, research integration, concept design, sponsorship.
Lena Kellarmann: Business plan, prototype testing, performance validation.
Marc Phillippi: Project workflow/milestone management, prototyping, reagent integration.
Noor Ul Ain: Market research, research integration, prototyping, public affairs.
Pratham Sachin Patil: Molecular Recognition, reagent integration, lab and prototype testing.
Yingjie Wang: Molecular Recognition, reagent integration, prototyping, evaluation.

5.2. People who have given support

Prof. Dr. Andreas Blaeser (Supervisor): Academic supervision, strategic research direction, and institutional support.
Maria Gabriela Avila (Coach): Project coordination, review meetings, and deadline management advice.
Thorsten Euler (Coach): Expertise on printing and fabrication, and lab coordination
Leonie Marie Holderbach : Coaching and technical feedback on experimental design and presentations.
Tim Weber : Technical guidance, lab coordination, and advice on sensor design and testing

5.3. Sponsors and partners

Technische Universität Darmstadt: Laboratory facilities, academic supervision, and institutional support.
IOCTO GmbH: €2,500 financial grant and sponsored team T-shirts.
Bipharma: €1,000 financial support for operational costs and materials.
Bartels Microfluidics: Microfluidic pumps, tubing, and accessories for fluid handling.
Igus: 3D printing filament for prototyping housing and structural parts.

6 Final remarks

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8 Appendix

Appendix A:

Stakeholder Characterisation:

Stakeholder Type	Stakeholder Role *
Patients	**Initiator** - might know about the device and suggest it to their neurologist **Decision Maker** - will have the final say on whether they want to wear the product on their body and use it during their everyday life **End User** - source of data for the project, must be convinced enough to be willing to wear device on body
Family Members	**Decision Maker** - are a big part of a PD patient's everyday life, in some cases they are the person deciding on behalf of many concerns regarding the PD patient **End User** - may use the continuous levodopa data to support patients every day **Influence** - if they are convinced, likelihood increases that patients will use it
Neurologists	**Initiator** - will have the knowledge about the products existence and suitability for the patient **Decision Maker** - will prescribe product to patient **End User** - will profit themselves from the continuous levodopa data for more individualised and objective dosage decision - must fit into their clinical workflow **Influencer** - they are prescriber of the product, their knowledge and favour of the product influences patient access
Therapists (Physiotherapists, Speech Language Therapists, Occupational, Psychological)	**End User** - will benefit from the ongoing levodopa data themselves, enabling them to plan therapy sessions more effectively - must fit into their clinical workflow

Hospitals	**End User** - will profit from the continuous levodopa data for better informed treatment of PD patients in a hectic clinic schedule - must fit into their clinical workflow **Payer** - large financial resources - big market share once entered their eco system **Influence** - key opinion leadership - important contact for validation study
Parkinson Clinics	**End User** -will profit themselves from the continuous levodopa data for more individualised and objective dosage decisions - must fit into their clinical workflow **Payer** - large financial resources - big market share once entered their eco system **Influence** - key opinion leadership - important contact for validation study - suitable option for market entry
Pharmaceutical companies	**End User** - use continuous levodopa monitoring for clinical studies of new medications
Caregivers (Nurses, home caregivers)	**End User** - will profit from the continuous levodopa data for better informed treatment of PD patients in a hectic clinic schedule
Regulatory Bodies	**Regulator** - provides essential requirements for product development, market entry and aftercare - decides on product approval for market entry 1. European Commission (EC) establishes regulatory framework through Medical Device Regulation (MDR) 2. In Germany, Notified Bodies assess conformity and issue the certificates required for CE marking, which enables market entry 3. Regulatory authorities, such as the Bundesinstitut für Arzneimittel und Medizinprodukte (BfArM) and state authorities, oversee regulatory compliance and market surveillance
Reimbursement decision-makers	**Regulator** -The Federal Joint Committee (G-BA) and the Institute for Quality and Efficiency in Health Care (IQWiG) evaluate the clinical benefits and eligibility for reimbursement of medical devices. **Payer** - Health Insurances are paying for the product once prescribed by a neurologist. The conditions under which costs are taken care of by the insurance compared to self-payment must be considered to ensure a cost efficient product selling strategy.

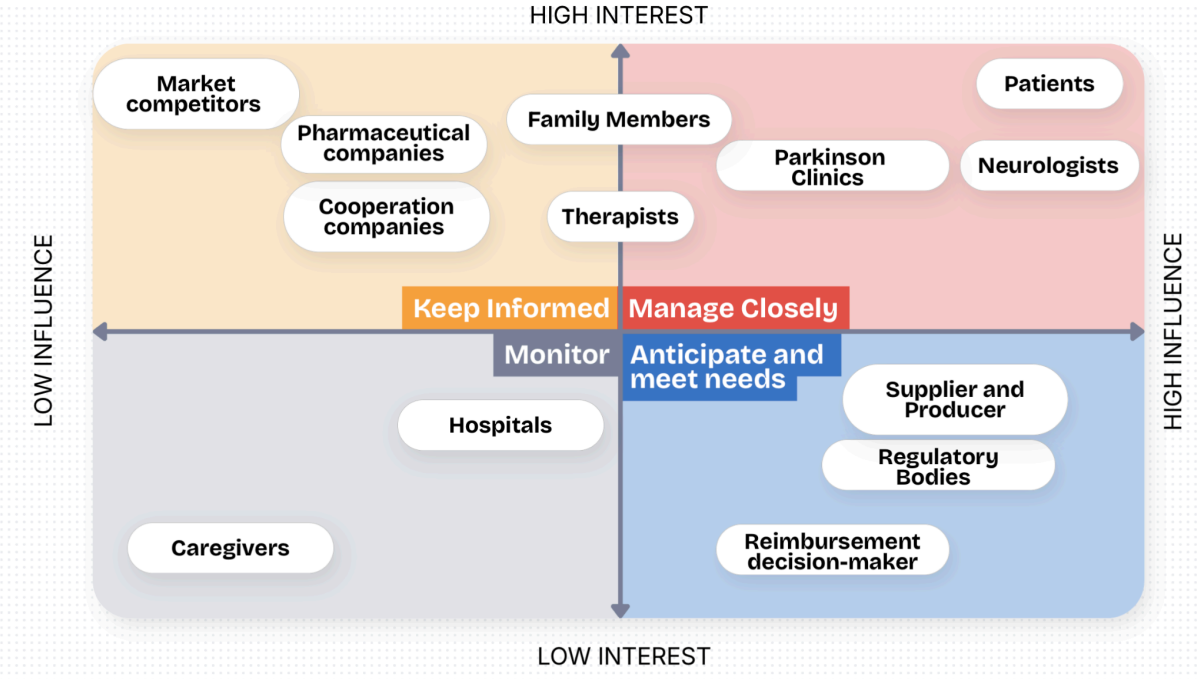
Cooperation companies	**Influence** - strategic cooperations can increase market entry speed and brand trust 1. Startup *Pheal* is working on wearable sensor integration platform technology. Could be a suitable partner for a wearable solution. 2. Startup *Toolip* is working on smarter user interfaces in symptom trackers for PD patients. Can provide intelligent UI design. 3. Companies that could directly benefit from supplementing their products with our technology (eg. Levodopa pump company *Abbvie care*) could be future customers. 4. PD management technology like symptom tracking (e.g. *Adamant Health, Orbit Health*) is useful information if combined with levodopa levels. 5. Similar technical approaches focused on a different problem like glucose sensors (e.g. *Dexcom, Abbott*) can deliver a platform for a wearable device.
Market competitors	**Influence** - Competitors' clinical evidence, reimbursement status, and regulatory approvals can influence market entry barriers - influences market positioning and target group selection 1. Startup *Pheal* is working on wearable sensor integration platform technology. Through potential partnership with another company specializing in levodopa measurement in ISF, they could accelerate development and potentially reach the market ahead of us. 2. Companies that could directly benefit from supplementing their products with our technology (eg. Levodopa pump company *Abbvie care*) might develop the measurement method themselves or through potential partnership with another company specializing in levodopa measurement in ISF, they could accelerate development and potentially reach the market ahead of us.
Suppliers/ Producers	**Influence** - access to reliable partners influences several aspects such as product quality and reliability, cost and pricing and regulatory compliance

***Stakeholder Role**

- Initiator: Identifies the need for the product, suggests, recommends or prescribes it
- Decision maker: Making the final decision on whether to proceed with a purchase
- Payer: Handling the actual procurement process including negotiations and contracts
- Regulator: Defining rules and laws required to follow
- End User: Using the product once it’s acquired
- Influence: Has any other influence on success or failure of the product

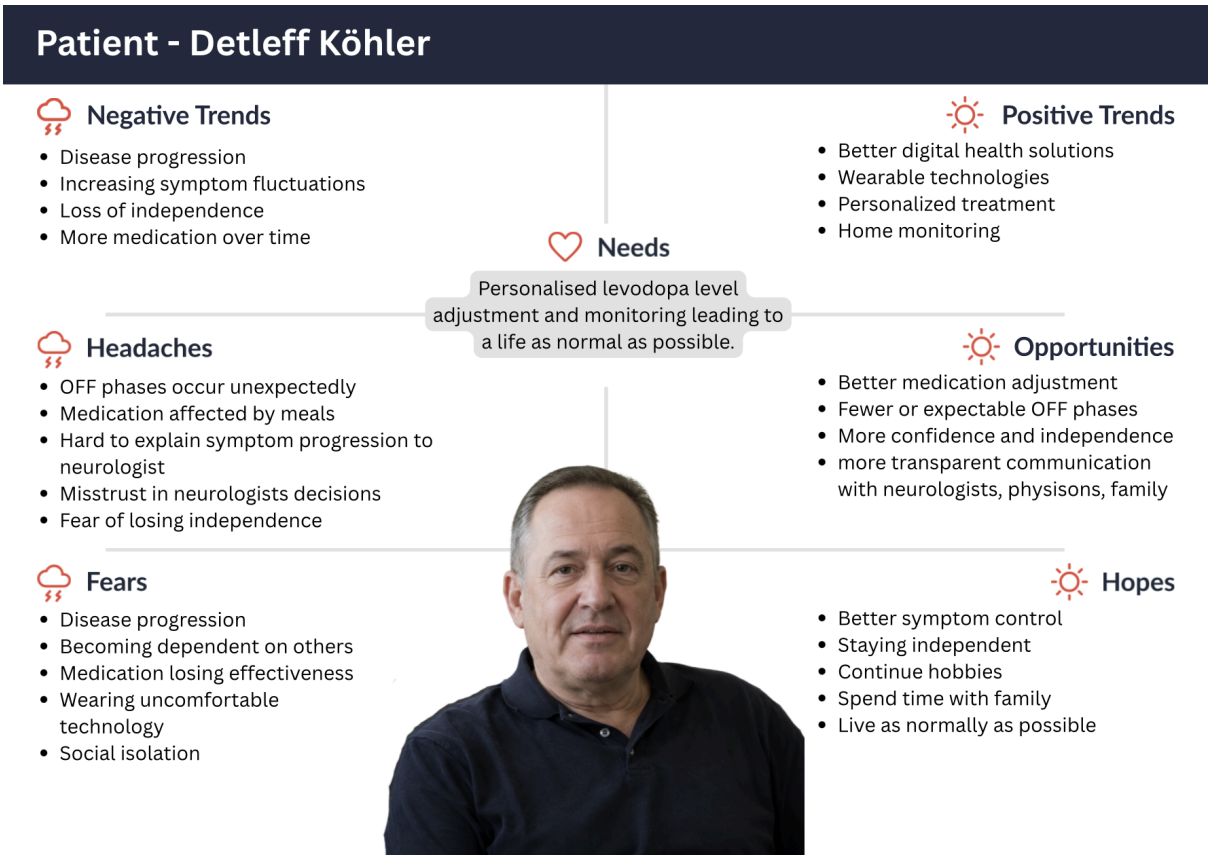
Appendix B:

Interest-influence matrix:



Appendix C:

Persona of a Parkinon's patient suffering from medication fluctuations.



Appendix D:

Persona of a Parkinson's Clinic Neurologist.

Neurologist - Dr. Julia Klauser

Negative Trends

- Increasing number of Parkinson patients
- Growing workload
- Short consultation times
- Aging population

Positive Trends

- Personalized medicine
- Wearable sensors
- Digital health
- Continuous monitoring
- AI-supported medicine

Needs

Objective, continuous information about patients levodopa absorption that improve clinical decision making without increasing workload.

Headaches

- Patient reports are subjective
- Difficult to optimize Levodopa dosage
- Symptoms fluctuate strongly
- Limited consultation time

Opportunities

- More objective treatment decisions
- Earlier detection of medication problems
- Better therapy personalization
- Better documentation
- Improved clinical studies



Fears

- Technology without clinical benefit
- Poor patient compliance
- Difficult integration into workflow
- False measurements

Hopes

- Reliable objective biomarker for levodopa dose adjustement
- Reduced uncertainty about patient compliance
- Better patient outcomes

Appendix E:

Participating stakeholder numbers per interview format

Stakeholder group	One-on-One	Online Questionaire	Group Interview	No.
Neurologists	Neurologist A Neurologist B Neurologist C Neurologist D Neurologist E Neurologist F Neurologist G	4	/	11
Patients	Patient A Patient B Patient C Patient D Patient J Patient K	5	Patient E Patient F Patient G Patient H Patient I	16
Family Member	Family Member C	1	Family Member A Family Member B	4
Therapists	Therapist A Therapist B Therapist C Therapist D	1	/	5
			Total	26

Appendix F:

Interview guidelines:

How to use this guideline

This guideline provides suggestive interview questions. The questions are structured into topics. Every topic is divided into sub sections as follows:

A: Try to identify problems.

B: How important are problems coming from A?

C: What solutions did they try to overcome identified problems from B?

D: Why is the current solution better than solutions in C?

In every topic the interview partner's pain points need to be identified. If you assume a piece of information from A is relevant you can prove it in B. If an important information is identified take it to C and D to illuminate on the solutions they have been working with.

Try to follow your intuition when having the interviews. That also means not every question must be asked. Interview partners may not feel comfortable with answering or individuals will not be able to provide the information. Alternatively a question might already have been answered during the conversation. If time is too short, topics or questions must be prioritized. Feel free to ask questions not in the list if required, dig deep until you find the information you need. You can use the First Question to get the conversation going and pick a topic. Last Questions can be used to end the conversation if time allows.

FIRST QUESTION

Could you talk me through your last day?

→ How was the day structure, symptoms, family life, doctor visits, medication intake,.....

LAST QUESTIONS

Is there anything else I should have asked?

Who else can I talk to (other than patients and doctors), e.g. Family members/ nurses?

Questions for Doctors & Therapists / Specialists

BACKGROUND

▪ Specialty / role (Neurology, GP, Geriatrics, other)

▪ Years treating Parkinson's patients

▪ Current PD patient caseload

▪ How often do you typically see a given PD patient?

SYMPTOMS

▪ Which symptoms most influence your treatment/therapy decisions?

▪ Which symptoms are hardest to assess in a routine visit or session?

▪ How confident are you that one visit reflects a patient's daily symptom burden?

▪ How much does symptom severity vary between appointments?

▪ How difficult is it to track symptoms outside the clinic?

▪ How well can you judge severity within a session, and how much does it affect the session's effectiveness?

▪ Biggest challenge assessing symptoms, and how do you work around it?

LEVODOPA & MEDICATION

▪ How often do you adjust a patient's dose, and on what factors?

▪ How hard is it to find the optimal dose?

▪ How confident are you that patients follow their prescribed schedule?

▪ How often does non-adherence or bad timing affect outcomes?

▪ How hard is it to tell OFF phases from dyskinesia?

▪ What tools do you currently use to guide dosage changes?

▪ How do you currently decide a dose needs adjusting?

COMMUNICATION

▪ How often do communication difficulties arise, and what form do they take?

▪ How important is efficient communication to a good outcome?

▪ How often / how much do family & caregivers contribute useful information?

▪ How valuable is caregiver input for tracking disease progression?

▪ How often do you communicate with the patient's physician?

▪ Biggest communication challenge, and how do you handle it?

MONITORING NEEDS

▪ Which inter-visit information would be most valuable to you?

▪ How useful would continuous monitoring of adherence / Levodopa efficacy be?

▪ How much would objective monitoring data improve dosing decisions?

▪What information do you wish you had between appointments, and how do you compensate now?

APPOINTMENT SCHEDULING

▪ How strongly does PD affect scheduling?

▪ What factors matter most (medication timing, caregiver availability, transport, etc.)?

▪ How often do appointments need to shift for symptom fluctuations?

▪ How hard is it to schedule during a patient's ON phase?

▪ Biggest scheduling challenge, and how do you solve it?

HOME EXERCISES

▪ Do you prescribe home exercises, and how important are they to outcomes?

▪ How confident are you that patients do them correctly?

▪ What are the biggest barriers to home-exercise adherence?

▪ Biggest challenge with home exercises, and how do you handle it?

WORKLOAD

▪ How would you describe your current workload?

▪ How much of it comes from the challenges above?

▪ How much does workload / limited time affect care quality?

▪ How long do you typically spend per appointment or session?

▪ What drives your workload most, and how do you cope?

FUTURE SOLUTIONS

▪Rate potential benefits 0–5: accurate dosing, OFF/dyskinesia detection, symptom tracking, adherence monitoring, earlier progression detection, patient / caregiver / neurologist communication, reduced workload, scheduling, exercise monitoring, therapy planning

▪ Any other solutions you'd want? Rate importance 1 – 5.

▪ What would stop you adopting a Levodopa-tracking device? (cost, workflow fit, privacy, reliability, patient acceptance, evidence, regulatory)

▪ Anything else about PD treatment / therapy challenges you'd like to share?

Questions for Patients & Family Members

BACKGROUND

▪ Age range
▪ Years since diagnosis
▪ How often do you see your doctor for PD?
▪ Do you currently take Levodopa?

SYMPTOMS
▪ Which symptoms affect your daily life most / are the biggest challenge?
▪ How much do symptoms vary day-to-day, and within a single day?
▪ Biggest daily-life challenge from your symptoms?

MEDICATION
▪ How hard is it to take medication at the right times?
▪ How often do you miss or delay a dose?
▪ How confident are you that your schedule is optimized for you?
▪ How often do you get “OFF phases”, and how many times when they occur?
▪ How easily can you tell when your medication is working or wearing off?
▪ Do you track your symptoms or medication schedule?
▪ Biggest medication challenge, and how do you manage it?

COMMUNICATION
▪ How easy is it to explain your symptoms to your doctor?
▪ How confident are you that your doctor understands how PD affects your daily life?
▪ Do you forget important information during appointments?
▪ How often are family or caregivers involved in your appointments?
▪ Biggest communication challenge with your care team?

THERAPY & HOME EXERCISES
▪ Do you currently do physio, OT, or speech therapy? Which kind?
▪ Do you exercise at home, and how important is that to managing symptoms?
▪ What makes it hard to exercise regularly?
▪ Biggest challenge with therapy or home exercises?

DAILY LIFE
▪ How much does PD affect your daily activities, and which ones most?
▪ How often do you worry about symptoms worsening?

▪ What aspect of PD affects your quality of life the most?

FUTURE SOLUTIONS

▪ Which information would help you manage symptoms better? (reminders, symptom / ON - OFF tracking, exercise reminders, fall detection, sleep / activity monitoring, doctor communication)

▪ Rate potential benefits 0 – 5: symptom tracking, medication timing, doctor / caregiver communication, earlier detection of worsening, independence, confidence, therapy planning

▪ Any other solutions you'd want? Rate importance 1 – 5.

▪ What concerns would a continuous Levodopa - monitoring device raise? (cost, privacy, comfort, tech difficulty, reliability)

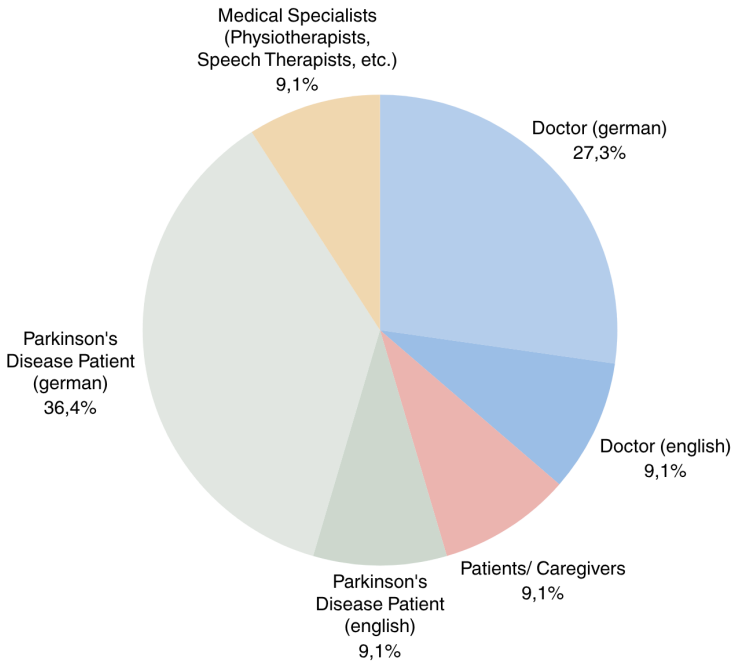
▪ Anything else about living with PD you'd like to share?

Appendix G:

Links to German online questionnaire: https://forms.gle/Jmo7rxPt4HdhLtvd6

Link to English online questionnaire: https://forms.gle/vnMUytWTiF2jcBKn6

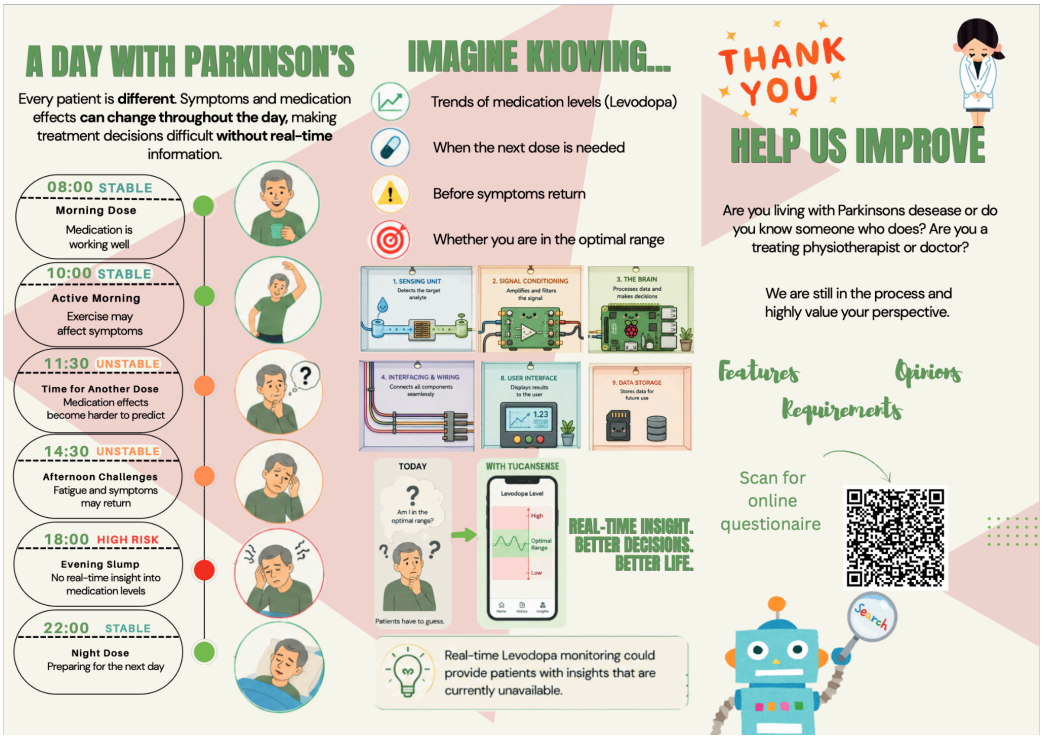
Composition of online questionnaire participants (n=11) :



Appendix H:

Flyer with QR





Appendix I:

Codebook showing interview results from one-on-one and group interviews.

Code	NR-A	NR-B	NR-C	NR-D	NR-E	NR-F	NR-G	Sum	%	SI-A	PH-B	PH-C	OT-D	Sum	%	PT-A	PT-B	PT-C	PT-D	PT-E	PT-F	PT-G	PT-H	PT-I	PT-J	PT-K	Sum	%	FM-A	FM-B	FM-C	Sum	%	Total	Total %
A1	0	1	1	1	1	1	1	6	86%	0	1	0	1	2	50%	0	1	0	1	0	0	0	0	0	0	1	3	27%	0	1	0	1	33%	12	48%
A2	0	1	1	1	1	1	1	6	86%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	7	28%
A3	0	0	0	0	0	1	1	2	14%	0	0	1	1	2	50%	0	1	1	1	0	1	0	0	0	0	1	5	45%	0	1	0	1	33%	9	36%
A4	0	0	0	1	0	1	1	3	43%	0	0	0	0	0	0%	1	1	0	0	0	0	0	0	0	0	1	2	18%	0	0	0	0	0%	5	20%
A5	0	0	1	1	0	1	1	4	57%	0	0	0	0	0	0%	1	0	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	5	20%
B1	0	1	0	0	0	0	1	1	14%	0	0	0	0	0	0%	0	1	0	0	0	0	1	0	1	0	3	3	27%	0	0	1	1	33%	5	20%
B2	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	0	0%
B3	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	1	1	33%	2	8%
B4	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	3	3	27%	0	0	0	0	0%	3	12%
C1	0	0	0	0	0	0	0	0	0%	0	1	0	0	1	25%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
C2	0	1	0	0	0	0	1	1	14%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
C3	0	0	0	0	0	1	1	1	14%	1	1	0	0	2	50%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	1	1	2	67%	6	24%
C4	0	1	0	1	0	0	0	2	29%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	2	8%
C5	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	0	0	1	0	0	1	0	0	0	3	3	27%	0	0	1	1	33%	4	16%
C6	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	1	0	0	0	0	5	5	45%	0	0	1	1	33%	6	24%
C7	0	0	0	0	0	0	0	0	0%	1	1	0	0	2	50%	0	0	1	0	0	0	0	1	0	0	2	2	18%	0	0	0	0	0%	4	16%
C8	0	0	0	0	0	0	0	0	0%	0	1	0	0	1	25%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
D1	0	0	0	0	0	1	1	2	50%	0	1	0	1	2	50%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	3	12%
D2	0	0	0	0	0	0	0	0	0%	0	1	1	1	3	75%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	3	12%
D3	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	0	0	1	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	1	4%
D4	0	1	0	1	0	0	0	2	29%	0	0	0	0	0	0%	0	1	0	0	0	0	0	1	0	0	2	2	18%	1	1	1	3	100%	7	28%
D5	0	0	0	0	0	0	0	0	0%	0	0	0	1	1	25%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	1	0	1	33%	2	8%
E1	0	1	0	1	0	1	1	4	57%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	5	20%
E2	0	0	1	0	1	0	1	3	43%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	3	12%
E3	1	0	0	0	0	0	0	1	14%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
E4	0	0	0	1	0	0	0	2	29%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	2	8%
E5	0	0	1	0	0	0	0	1	14%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	2	8%
F1	0	1	0	0	1	0	0	2	29%	0	1	0	0	1	25%	0	1	0	0	0	0	0	0	0	0	1	3	27%	0	0	0	0	0%	6	24%
F2	0	0	0	0	0	0	0	0	0%	0	1	0	0	1	25%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
F3	0	0	0	0	0	0	0	0	0%	0	1	0		1	33%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
F4	1	0	0	0	0	0	1	1	14%	1	0	0	0	1	25%	0	0	1	1	0	0	0	0	0	0	2	2	18%	0	1	1	2	67%	6	24%
F5	0	1	0	0	0	0	1	1	14%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	2	8%
F6	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	1	4%
F7	0	0	0	0	1	0	1	1	14%	0	0	0	0	0	0%	0	0	0	1	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	2	8%
F8	0	0	0	0	1	0	1	1	14%	0	0	0	0	0	0%	0	0	0	1	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	2	8%
G1	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	1	0	0	0	1	0	0	0	0	0	3	3	27%	0	0	0	0	0%	3	12%
G2	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	1	0	0	0	1	0	0	1	0	0	3	3	27%	0	0	0	0	0%	3	12%
H1	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	1	4%
H2	0	0	0	0	0	0	0	0	0%	0	0	0	0	0	0%	0	1	0	0	0	0	0	0	0	0	1	1	9%	0	0	0	0	0%	1	4%
I1	0	0	0	0	0	0	1	1	14%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	1	4%
I2	0	0	0	0	0	0	1	1	14%	0	0	0	0	0	0%	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%	2	8%

Codebook Legend:

NR-A	Neurologist A
NR-B	Neurologist B
NR-C	Neurologist C
NR-D	Neurologist D
NR-E	Neurologist E
NR-F	Neurologist F
NR-G	Neurologist G
SL-A	Speech-language pathologist A
PH-B	Physiotherapist B
PH-C	Physiotherapist C
OT-D	Physio-/ ergotherapist D
PT-A	Patient A
PT-B	Patient B
PT-C	Patient C
PT-D	Patient D
PT-E	Patient E
PT-F	Patient F
PT-G	Patient G
PT-H	Patient H
PT-I	Patient I
PT-J	Patient J
FM-A	Family member / caregiver A
FM-B	Family member / caregiver B

Codebook Guide:

Theme with Code	**Stakeholder types**	**Definition**
Theme A - Data gaps & clinical uncertainty		
A1: data-gap-between-visits	NR/ PT/ PH / OT	Clinician, patient or therapist describes having no reliable information about levodopa levels or symptoms between appointments.
A2: dose-adjustment-blind	NR	Clinicians describe making dosing decisions largely on clinical observation, without objective pharmacokinetic feedback.
A3: unpredictable-off-onset	PT / PH / OT	Patient or therapist describes inability to predict when OFF-periods will begin.
A4: food-drug-interaction-unaware	PT / NR	Interviewee describes struggling to manage how food timing affects levodopa absorption.
A5: absorption-variability-unknown	NR	Clinicians express that gastrointestinal absorption of levodopa is highly individual and

		effectively unmeasurable today, undermining dosing confidence.
Theme B - Workarounds & coping behaviour		
B1: diary-use-and-abandonment	PT / NR	The patient started a symptom diary but stopped, or clinician describes receiving unreliable/incomplete diary data.
B2: informal-clinician-contact	PT / NR	Patient contacts treating clinician outside formal appointments to report symptom changes.
B3: activity-restriction	PT	Patients limit activities, plans or social events due to fear of unpredictable OFF-periods.
B4: dose-self-adjustment-undisclosed	PT	The patient adjusts dose (amount or timing) independently, frequently without disclosing this to their physician.
Theme C - Technology acceptance & barrier		
C1: wearability-concern	PT / NR	Interviewee raises concern about comfort, discretion, or practicality of wearing a sensor continuously.
C2: app-fatigue	NR / PH / OT	Clinicians expressed reluctance to adopt another software platform or app into an already fragmented workflow.
C3: smartphone-vision-dexterity-barrier	PT / SL / PH	Patient describes limited smartphone/touchscreen use due to age, tremor, dexterity or visual symptoms of PD.
C4: data-trust-concern	NR	Clinicians question whether sensor data would be accurate/validated enough to act on clinically.
C5: dedicated-device-preference	PT	Patients prefer a simple, separate/dedicated device over a smartphone app, to reduce confusion; simplest form suggested is a red/amber/green indicator.
C6: tiered-vs-shared-data-debate	PH / NR / SL / FM / PT	Explicit design tension: some stakeholders want data complexity tiered by role (simple for patients, full detail for clinicians); others want doctors and patients to see identical, shared data.
C7: alert-reminder-fatigue-risk	PH	Concern that behavioural nudges/reminders lose effectiveness or annoy patients as disease progresses.
Theme D - Care coordination & workflow		
D1: inter-professional-gap	PH / NR / OT	Therapist and neurologist/other professional describe not sharing information about the patient's current state.
D2: therapy-timing-suboptimal	PH / OT	Therapist describes scheduling rehab sessions without knowing when the patient will be in an ON state.
D3: appointment-frequency-mismatch	PT / NR	The patient or clinician notes that scheduled appointments are too infrequent for effective, timely dose management.

D4: family-mediation-role	FM / NR / PT	Family member/caregiver acts as an informal clinical sensor, managing medication and noticing changes the patient does not notice themselves.
D5: doctor-therapist-report-blackhole	OT / PH	Therapist reports/letters sent to treating physicians are not read or acted upon, breaking the care loop.
Theme E - Reimbursement & adoption barriers		
E1: cost-coverage-uncertainty	PT / NR	Interviewee unsure who pays for a continuous monitoring device, or concerned it will not be covered by insurance.
E2: evidence-requirement	NR	Stakeholders state that clinical evidence of outcome improvement is required before adoption or reimbursement.
E3: liability-concern	NR	Clinicians raise concern about liability if a dosing decision made on sensor data turns out to be wrong.
E4: budget-cap-constraint	NR	Clinicians describe a fixed per-patient-day reimbursement budget (Tagessatz) that any device must fit within, independent of its clinical merit.
E5: prescription-gatekeeping	NR / PT	Adoption of an at-home device requires physician approval/prescription; the physician is a mandatory gatekeeper, not just an end-user.
Theme F - Multimodal monitoring & feature-expansion desire		
F1: gait-mobility-monitoring-desire	PH / NR / PT	Stakeholders want the device to track gait, mobility or fall risk alongside levodopa levels.
F2: exercise-compliance-tracking	PH	Therapist wants the device to verify whether prescribed home exercises were actually completed.
F3: smart-equipment-integration	PH	Therapist suggests integration with smart training equipment used in rehab.
F4: dose-reminder-app-desire	NR / SL / PT	Stakeholders want an automated, individualised reminder to take the next levodopa dose.
F5: tremor-freezing-alert-desire	PT / NR	Stakeholders want active detection of / alerting on tremor and freezing-of-gait episodes, not only passive logging.
F6: sleep-monitoring-desire	PT	Stakeholders want sleep quality / micro-sleep data included alongside levodopa data.
F7: predictive-pre-off-alert-desire	NR / PT	Stakeholders want a predictive warning before an OFF period begins (not merely retrospective detection), so the patient can act pre-emptively.
F8: correlation-with-external-trackers	NR / PT	Stakeholder wants levodopa data overlaid/correlated with data from existing wearables or clinical tracking devices (e.g. mobility watch, KINESIA 360).
Theme G - Trust & shared decision-making		
G1: medication-distrust	PT	The patient expresses distrust of the prescribed medication or dose itself, independent of the monitoring problem.

G2: objective-data-as-trust-bridge	PT / FM	Stakeholder frames shared objective sensor data as a way to rebuild or strengthen trust between patient and physician.
Theme H - Patient safety & emergency use		
H1: narcosis-drug-interaction-risk	PT	Patient describes a dangerous interaction between anaesthesia/narcosis medication and PD medication that is not universally known among non-specialist clinicians.
H2: emergency-medical-info-access-desire	PT	Patients want fast, passive access to critical medical information (medications, contraindications) in an emergency.
Theme I - Market channel diversity		
I1: clinical-trial-pharma-channel	NR	Clinicians identify pharmaceutical / clinical-trial sponsors as a distinct customer segment, separate from patients and treating physicians.
I2: pd-clinic-inpatient-pathway	PT / NR	Stakeholder references structured, insurance-funded inpatient PD clinic stays (~2 weeks/year) as an existing, underused touchpoint for adoption.

Appendix J:

Quotes from interviews organised by codes:

Interview ID	Stakeholder role	Quote
A1: Data-gap-between-visits		
NR-C	Neurologist	"A single measurement is useless, it has to be this continuous measurement."
NR-B	Neurologist	"Objective data could help to better contextualise subjective assessments."
+NR-D	Neurologist	"Every now and then we have patients where we just don't know if they are absorbing enough."
NR-E	Neurologist	"You don't know how much L-Dopa reaches the brain."
NR-F	Neurologist	"It is not yet investigated how exactly levodopa in blood is correlating with symptoms, very interesting."
PH-B	Physiotherapist	"It would be nice to know the ideal time for patients to have their physiotherapy session in terms of symptoms."
OT-D	Physio-/ergotherapist	"It's not possible to fully plan a therapy session, because the patient's state varies that much."
PT-D	Patient	"I am very interested in these kinds of trend data."
PT-B	Patient	"Continuous monitoring would be enormously helpful, especially if you forget your medication."
A2: Dose-adjustment-blind		
NR-C	Neurologist	"Adjustments to medication dosage are based primarily on clinical observations such as recurring symptoms, changes in mobility, and patient reports."
NR-B	Neurologist	"Levodopa levels should be correlated with clinical data. Comparing objective measurement data with subjective perceptions could be particularly helpful for patients in the middle to late stages of the disease."
NR-D	Neurologist	"Dosage adaptation is very individual, dependent on age, daytime structure" - and could be improved with "information on Levodopa absorption to offer a more individualised dosage."
NR-E	Neurologist	"Parkinson's isn't like blood pressure - it's individual."
NR-F	Neurologist	"Usually you say half an hour or one hour patients should not eat so Levodopa can be absorbed by the gut, but maybe there are patients that need less or even 2 hours, and we cannot know."
A3: Unpredictable-off-onset		
PH-C	Physiotherapist	"No day is the same. You have to be spontaneous and see each day what's possible."
PT-B	Patient	"You always enter an off phase, but you don't always notice it, depending on the situation."
PT-A	Patient	"Major frustration is day-to-day unpredictability. Same conditions can yield vastly different outcomes."
PT-D	Patient	"I don't notice when coming in an OFF, my wife notices."
OT-D	Physio-/ ergotherapist	"It's not possible to fully plan a therapy session, because the patient's state varies that much."

A4: Food-drug-interaction-unaware		
PT-B	Patient	"Fish neutralises Parkinson's tablets… generally nothing to eat for 2h after taking the tablets."
NR-F	Neurologist	"Usually you say half an hour or one hour patients should not eat so Levodopa can be absorbed by the gut, but maybe there are patients that need less or even 2 hours, and we cannot know."
NR-D	Neurologist	Absorption is "dependent on food, intestine health"… "highly individual and currently unmeasured."
PT-E	Patient	"Digestive problems caused by the disease… will impact levodopa absorption."
A5: Absorption-variability-unknown		
NR-D	Neurologist	"It's possible that you give two patients like twin brothers the same dose and still different amounts reach the blood, for various reasons… nobody has [investigated] absorption rates over time."
NR-F	Neurologist	"There have been studies on ISF brain concentration when there is a certain amount in the blood… surely there will be some kind of a quotient between the levodopa concentration in blood to ISF that you can find out."
NR-C	Neurologist	"Gastrointestinal problems such as gastroparesis can delay the absorption of the medication, making it difficult to determine when the medication actually reaches an effective concentration in the body."
PT-E	Patient	Trust issues with her neurologist arose because "the prescribed dose did not work and the physician provided inconsistent information regarding the influence of digestive problems" on absorption.
B1: Diary-use-and-abandonment		
NR-B	Neurologist	"…activity logs kept by patients are frequently incomplete or unreliable."
PT-B	Patient	"Most people track symptoms, but I'm too lazy for that - I have too much other volunteer work to do."
PT-H	Patient	"The patient does not document symptoms or wellbeing… describes his condition to the physician based on his subjective impression."
PT-I	Patient	"Does not document symptoms or wellbeing. Describes his condition spontaneously during physician visits."
B3: Activity-restriction		
PT-D	Patient	"The worst were not my colleagues, it was society, because I didn't get accepted anymore… I still drive but will stop in the coming 6 months. It gets too dangerous."
PT-B	Patient	"My circle of friends has become smaller.")
B4: Dose-self-adjustment-undisclosed		
PT-F	Patient	"I take less medication than prescribed.: Prescribed are 3 x 100 mg, but I take 3 x 50 mg. I don't fully trust the medication the doctor prescribed me. I'm not telling him."
PT-D	Patient	"I take them when I want, I don't want to let my life be dominated by pills. Sometimes I am already asleep when I

		should take them in the evening. But forgetting is the main reason."
PT-G	Patient	"I feel good with this dose, why do you want to increase it?" [said to her physician, resisting a recommended dose increase]
C1: Wearability-concern		
PH-B	Physiotherapist	"Ideally the device is decent to wear and easy to handle, especially for older patients."
C2: App-fatigue		
NR-B	Neurologist	"...in everyday clinical practice, there is often not enough time to evaluate specialized apps or extensive datasets."
C3: Smartphone-vision-dexterity-barrier		
PT-D	Patient	"PD also affects your eyes, smartwatches are no option for me, I cannot even properly see what it shows me... I hate my tablet, because I really have to stand still to touch the right area."
PT-B	Patient	"The devices need to be simple to operate, older people don't know smartwatches and so on ."
SL-A	Speech-language pathologist	Patients are "normally older and Parkinson's disease has some negative effects on the ability to use things like smartphones." Their "ability to plan their actions and organise themselves is limited."
PH-B	Physiotherapist	"Patient user interface should not only be possible with smartphones. Older people cannot read it or handle it."
C4: Data-trust-concern		
NR-C	Neurologist	"Clinical validation and comparison with established reference measurements would be essential before its introduction into routine care."
NR-E	Neurologist	"New technologies should demonstrate clear additional clinical benefits before being integrated into routine practice."
C5: Dedicated-device-preference		
PT-G	Patient	"Prefers a separate device because it reduces confusion. The device could potentially be a simple indicator device with red/orange/green lights depending on the patient's condition."
PT-I	Patient	"User interface concept: split into a smartphone application (cheaper) and an optional separate device (hardware optimised for PD patients' needs)."
C6: Tiered-vs-shared-data-debate		
PH-B	Physiotherapist	"There should be a split information provision between medical professionals and patients in the user interface, allowing the professional's data to be more complex."
SL-A	Speech-language pathologist	The patient-facing application "has to be simple to use... as less complex as possible!"
C7: Alert-reminder-fatigue-risk		
PH-B	Physiotherapist	"Patients could get reminded, if they fall into bad walking patterns or posture, however, this is probably only useful to a certain extent and becomes more annoying with progression of the disease."

D1: Inter-professional-gap		
OT-D	Physio-/ergotherapist	"Reports are constantly being requested, but they probably aren't being read... there is very little communication between the doctors and therapists."
PH-B	Physiotherapist	"Especially a function for exchanging information between doctors and physiotherapists can help avoid information bias when information is only transmitted by the patient."
D2: Therapy-timing-suboptimal		
OT-D	Physio-/ ergotherapist	"It's not possible to fully plan a therapy session, because the patient's state varies that much" - it "would be beneficial to know in advance how the patient's symptoms are at the therapy session."
PH-B	Physiotherapist	"Finding session time slots [is] sometimes difficult, because patients need to take their medicine at certain times and symptoms get worse when medication wears off."
PH-C	Physiotherapist	"No day is the same. You have to be spontaneous and see each day what's possible."
D3: Appointment-frequency-mismatch		
PT-A	Patient	Tier 2 of his data model is scoped explicitly around "objective longitudinal data for biannual consultations" - his neurologist visits are roughly twice a year, which he treats as itself part of the problem.
D4: Family-mediation-role		
FM-A	Family member	The wife of a patient manages everything, from daily life over medication intake to appointments. She had to carry a printed medication schedule with her.
FM-B	Family member	"I had to manage everything because his physical and communication abilities deteriorated."... "Remembering all symptoms and communicating them accurately to the physician was very difficult."
NR-B	Neurologist	"Family members are also frequently involved in the assessment."
NR-D	Neurologist	"Many times family members are part of the clinic stay." ... "If somebody has PD or not is something that influences the life of both partners extremely."
PT-D	Patient	"I don't notice when coming into an OFF, my wife notices when my voice gets louder or I get annoyed or tired easier."
D5: Doctor-therapist-report-blackhole		
OT-D	Physio-/ ergotherapist	"Reports are constantly being requested, but they probably aren't being read. The doctors sometimes lack a bit of logic."
E1: Cost-coverage-uncertainty		
NR-D	Neurologist	"Health insurances are paying, and give clinics the same amount of money no matter if the clinic decides for a more or less expensive version of a product."
PT-D	Patient	"Every patient is allowed to be treated in the PD clinic for two weeks every year, paid by the health insurance... 10 EUR per day must be paid by patients themselves."
NR-F	Neurologist	"Patients can take watches home with them, but have to pay for it themselves, only one insurance will pay for it" - and a

		hospital "gets a certain amount of money from health insurances for the patient's stay."
NR-B	Neurologist	"Processes such as applications for cost coverage should also be simplified as much as possible, so that, ideally, the doctor only has to fill in a few details or check a few boxes."
E2: Evidence-requirement		
NR-E	Neurologist	"New technologies should demonstrate clear additional clinical benefits before being integrated into routine practice."
NR-C	Neurologist	"Clinical validation and comparison with established reference measurements would be essential before its introduction into routine care."
E4: Budget-cap-constraint		
NR-D	Neurologist	"Clinics are paying for things with different budgets." ... You have to "make the product cheap enough so it fits into [the] budget that clinics get for a patient's treatment per day."
NR-F	Neurologist	"Hospitals get a certain amount of money from health insurance for the patient's stay - if [the] device fits into that budget, they will buy it."
E5: Prescription-gatekeeping		
PT-D	Patient	"I only get such a pump when my neurologist knows about it... health insurance pays for it, if [the] neurologist approves it."
NR-D	Neurologist	"If you prescribe something ambulatory to a patient, you must explain to health insurance."
F1: Gait-mobility-monitoring-desire		
NR-B	Neurologist	"General mobility, step count, freezing episodes, and walking ability should also be documented."
PH-B	Physiotherapist	"It would be great to measure their walking patterns to minimize the risk of fall or evaluate disease progression."
NR-F	Neurologist	Shown a mobility-tracker watch UI: "I would expect your device to show me data as an overlay over the mobility curve so that I can see the correlation."
PT-A	Patient	"Built-in accelerometers could supplement levodopa data with movement tracking."
F2: Exercise-compliance-tracking		
PH-B	Physiotherapist	"...I can't control[,] if the exercises have been done and to what extent and quality."
F3: Smart-equipment-integration		
PH-B	Physiotherapist	"Sensors can be combined with intelligent training equipment, e.g. HP Kosmos treadmill."
F4: Dose-reminder-app-desire		
NR-A	Neurologist	"...reminding the patients to take an individualized dose of levodopa" via a smartphone application.
SL-A	Speech-language pathologist	"The application which is reminding the patients to take levodopa has to be simple to use."
F5: Tremor-freezing-alert-desire		
PT-B	Patient	"For example an alarm on freezing helps, e.g. vibration, so the freezing episode is broken."

NR-B	Neurologist	"Recording tremor would also be useful… freezing episodes… should also be documented."
F6: Sleep-monitoring-desire		
PT-B	Patient	"How often do I fall asleep?"
F7: Predictive-pre-off-alert-desire		
NR-F	Neurologist	"They could get a notification to take their rescue medication before coming in an OFF, because some patients don't notice that."
PT-A	Patient	Useful real-time alerts include "Fall risk elevated or good time to eat," … “pre-emptive, not just reactive, prompts.”
F8: Correlation-with-external-trackers		
NR-F	Neurologist	"I would expect your device to show me data as an overlay over the mobility curve so that I can see the correlation."
PT-A	Patient	Previously used the "Parkinson Smartwatch (StrivePD/ClearSky)" and wants built-in accelerometers to "supplement levodopa data with movement tracking."
G1: Medication-distrust		
PT-F	Patient	"I do not fully trust the medication."
PT-G	Patient	"I’m dissatisfied with the medication because the effectiveness varies from day to day."
PT-E	Patient	"I took levodopa for a few months but discontinued it 4 months ago because I did not tolerate it well".
G2: Objective-data-as-trust-bridge		
PT-G	Patient	"I feel good with this dose, why do you want to increase it?"
PT-E	Patient	"…sensors can help strengthen trust between the doctors and us as we can talk about the same information."
H1: Narcosis-drug-interaction-risk		
PT-D	Patient	"Narcosis medications do not work well together. Certain narcosis medications should not be used for PD patients, but not all anaesthetists know about it." [patients stutter was still worse months after a narcosis]
H2: Emergency-medical-info-access-desire		
PT-D	Patient	Idea: "make [an] emergency QR code on the device" (outside), listing medications that PD patients are not allowed to receive.
I1: Clinical-trial-pharma-channel		
NR-F	Neurologist	"You will have 3 big customers: doctors, patients and pharma. Pharma will want to use the device for clinical studies on the effects of Levodopa."
I2: Pd-clinic-inpatient-pathway		
PT-D	Patient	"Patients are able to be treated in the PD clinic for two weeks every year, paid by the health insurance. Many don't know about that."
NR-E	Neurologist	Confirmed that ~2-week inpatient stays are "routinely used for medication optimisation", combining drug therapy with intensified physio-/occupational therapy.

Appendix K:

Market Segmentation sheet :

	Late onset Patient	Middle Onset Patient	Proactive Patient	Socially invested PD Patient	Patients in Parkinson's clinics	Outpatients	Patients treated by office-based neurologists	Physically active patient	
Group Description	Parkinson Patients older than 70 years	Parkinson patients between 50 and 70 years of age.	Actively seek ways to improve their quality of life and treatment.	Strong familiy support and active social environment.	Receive specialized care at dedicated Parkinson centers.	Receive regular treatment without hospitalization.	Primarily treated by resident neurologists in practice.	Regularly engage in physical activity and exercise.	
Target group size*	3 (~310.000 Patients)**	1 (~48.000 Patients)**	/	/	1 (~40.000 Patients)***	3 (~260.000 Patients)***	2 (~220.000 Patients)***	/	
How big is "pain"/ need for a solution	3	2	3	2	2	3	3	3	
Urgency to buy/ Willingness to buy now	3	2	3	2	3	2	2	3	
Financial Capabilities e.g. Health insurance, willingness to pay, Capital	1	3	/	/	2	1	1	/	
Openess to Technology	0	1	3	2	2	2	1	2	
Total	10	9	9	6	10	10	10	10	
	Demographic segmentation		Psychographic segmentation		Geographic segmentation			Behavioral segmentation	

Scores from 0 (no impact) to 3 (strong impact)

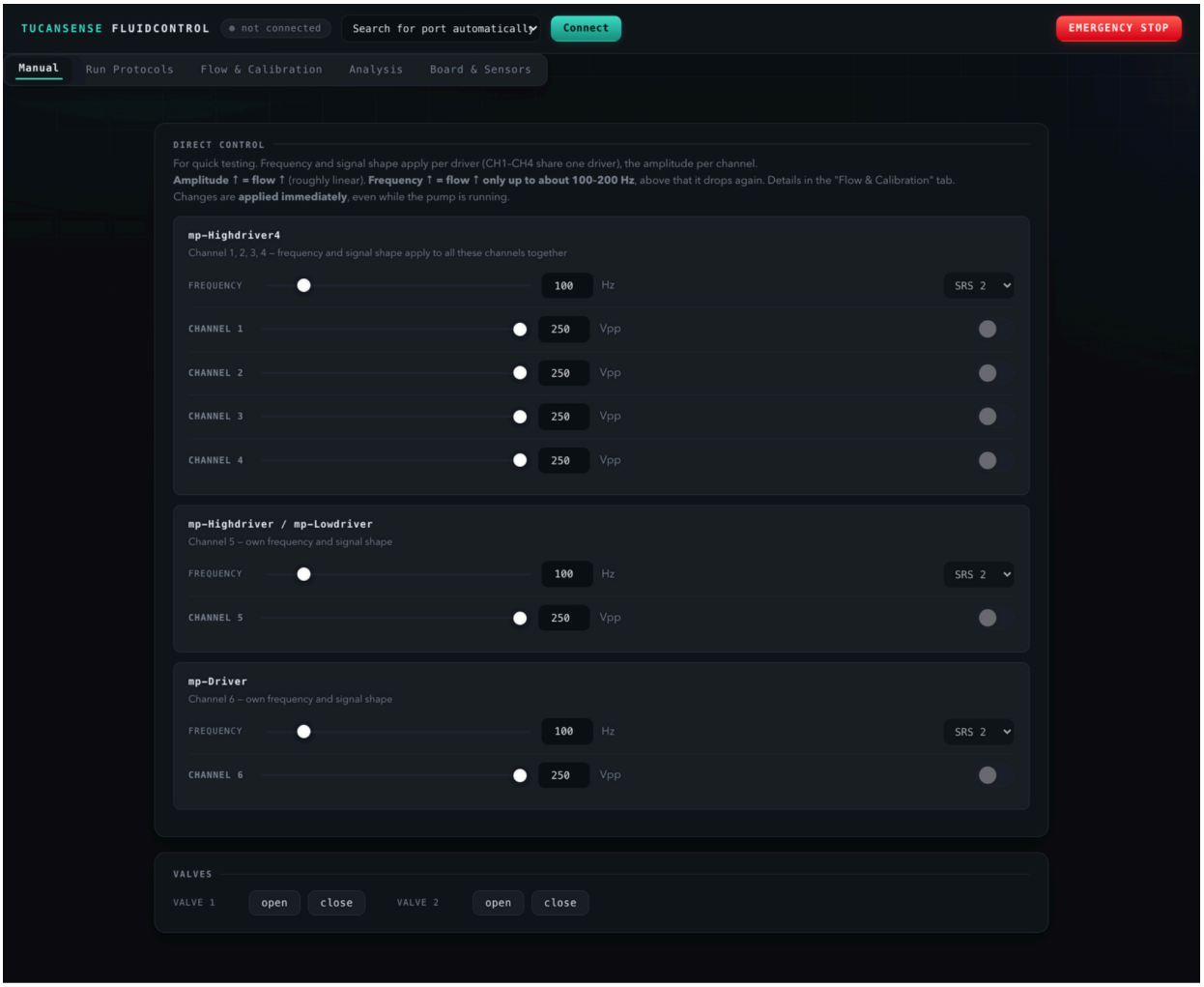
*Based on german incidents/ year

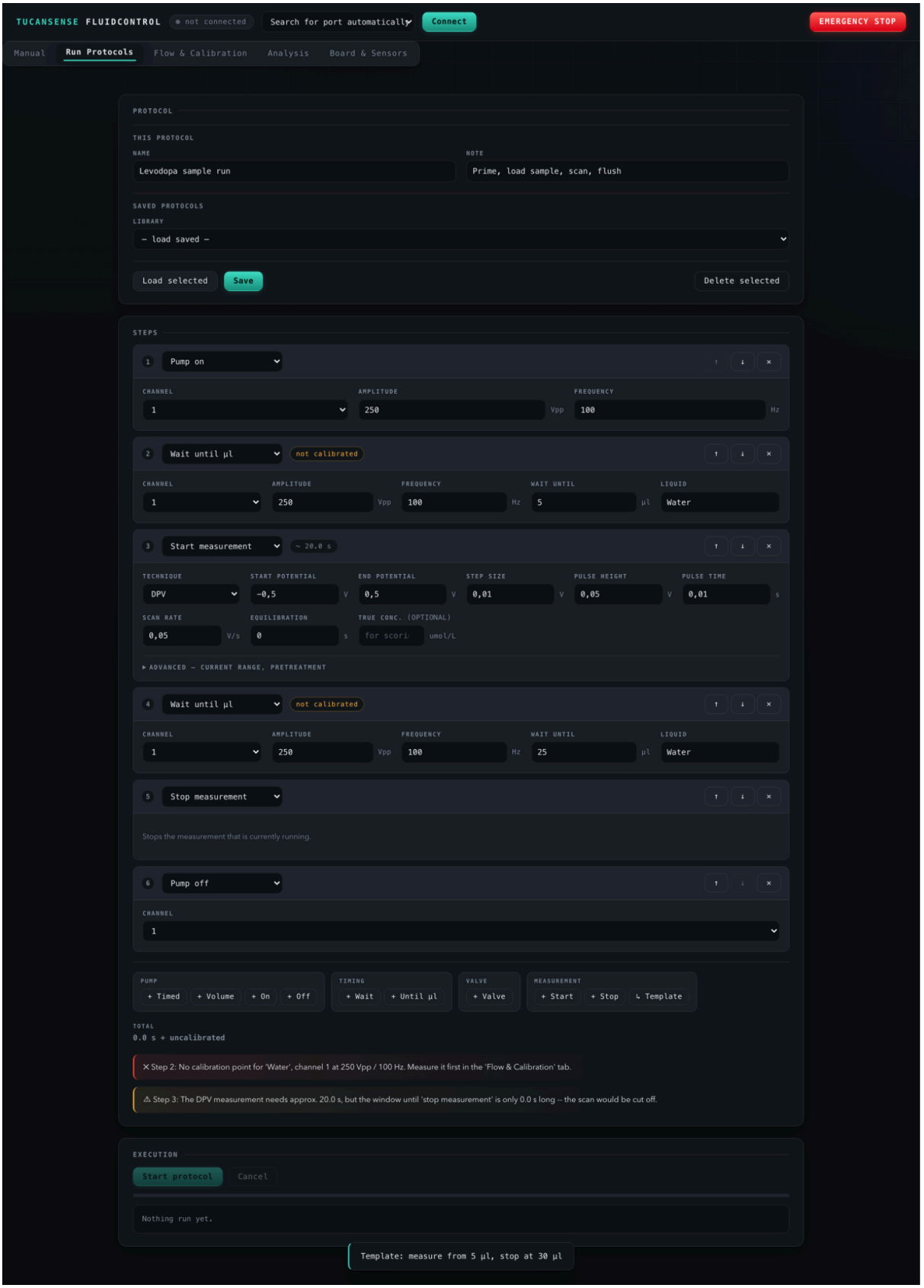
**Based on prevalence rates and age distribution

***Based on annual patient numbers estimated based on the total PD patient population in Germany, available healthcare utilization data, and typical care pathways. As detailed nationwide data on the distribution between specialized centers, outpatient care, and office-based neurologists is not available, values were derived using reported treatment data and reasonable assumptions.

Appendix L:

Reader Instrument, Interface




TUCANSENSE FLUIDCONTROL
not connected
Search for port automatically
Connect
EMERGENCY STOP
Manual
Run Protocols
Flow & Calibration
Analysis
Board & Sensors
PROTOCOL
THIS PROTOCOL
NAME
Levodopa sample run
NOTE
Prime, load sample, scan, flush
SAVED PROTOCOLS
LIBRARY
— load saved —
Load selected
Save
Delete selected
STEPS
1 Pump on
CHANNEL 1
AMPLITUDE 250 Vpp
FREQUENCY 100 Hz
2 Wait until µl
not calibrated
CHANNEL 1
AMPLITUDE 250 Vpp
FREQUENCY 100 Hz
WAIT UNTIL 5 µl
LIQUID Water
3 Start measurement
~ 20.0 s
TECHNIQUE DPV
START POTENTIAL -0,5 V
END POTENTIAL 0,5 V
STEP SIZE 0,01 V
PULSE HEIGHT 0,05 V
PULSE TIME 0,01 s
SCAN RATE 0,05 V/s
EQUILIBRATION 0 s
TRUE CONC. (OPTIONAL) for scori umol/L
▸ ADVANCED — CURRENT RANGE, PRETREATMENT
4 Wait until µl
not calibrated
CHANNEL 1
AMPLITUDE 250 Vpp
FREQUENCY 100 Hz
WAIT UNTIL 25 µl
LIQUID Water
5 Stop measurement
Stops the measurement that is currently running.
6 Pump off
CHANNEL 1
PUMP
+ Timed
+ Volume
+ On
+ Off
TIMING
+ Wait
+ Until µl
VALVE
+ Valve
MEASUREMENT
+ Start
+ Stop
↳ Template
TOTAL
0.0 s + uncalibrated
✕ Step 2: No calibration point for 'Water', channel 1 at 250 Vpp / 100 Hz. Measure it first in the 'Flow & Calibration' tab.
⚠ Step 3: The DPV measurement needs approx. 20.0 s, but the window until 'stop measurement' is only 0.0 s long -- the scan would be cut off.
EXECUTION
Start protocol
Cancel
Nothing run yet.
Template: measure from 5 µl, stop at 30 µl

TUCANSENSE FLUIDCONTROL · not connected · Search for port automatically · Connect · EMERGENCY STOP

Manual | Run Protocols | Flow & Calibration | Analysis | Board & Sensors

WHAT DO AMPLITUDE AND FREQUENCY DO?





Amplitude: intuitive. Above a switch-on threshold the flow rises roughly linearly with the voltage. More Vpp = more flow. Maximum 250 Vpp – above that the manual warns of overvoltage in the piezo.

Frequency: not monotonic. The flow rises up to about 100-200 Hz and then drops again – at 800 Hz it is almost zero. The manual even names high frequency as a method to deliberately *reduce* the flow (inertia and shear forces, ch. 3.12 Option B).

The curve shapes are qualitative (after Micropump Manual ch. 3.12) – they show the direction, not your numbers. The Highdriver can go down to 50 Hz, which per the manual corresponds to a lower flow of around 100 µl/min. For even less, only throttling helps, e.g. via a capillary.

CALIBRATION SWEEP

Flow **cannot** be computed from the settings – back pressure, tubing and viscosity shift it by orders of magnitude. And one weighing at one setting is not a calibration: it is a single sample of a noisy quantity. This sweeps **several amplitudes × several frequencies, repeated**, then fits flow against amplitude for each frequency.

STATUS Nothing measured yet. Plan a sweep below and work through it.

1 PLAN THE SWEEP

LIQUID: Water | CHANNEL: 1 | PUMP TIME EACH: 60 s | REPEATS: 3 ×

AMPLITUDES: 100, 150, 200, 250 Vpp
At least 3 for a meaningful fit. Comma separated.

FREQUENCIES: 50, 100, 200 Hz
Each gets its own fit – flow is not monotonic in frequency.

Save plan | Clear plan | 4 × 3 × 3 = 36 weighings · 36 min of pumping

2 RUN IT, WEIGHING AFTER EACH

No sweep planned yet – fill in step 1 and press **Save plan**.

3 THE FITTED MODEL

Not enough data yet: a fit needs at least two different amplitudes at the same frequency.

No fit yet

▸ ADD A SINGLE POINT BY HAND

MEASURED OPERATING POINTS

LIQUID	CH	VPP	HZ	FLOW (MEAN)	SD	CV	N

Nothing calibrated yet.

CONVERT VOLUME ↔ TIME

HOW MUCH DO YOU WANT TO MOVE?

TARGET VOLUME: 100 µl

AT WHICH OPERATING POINT?

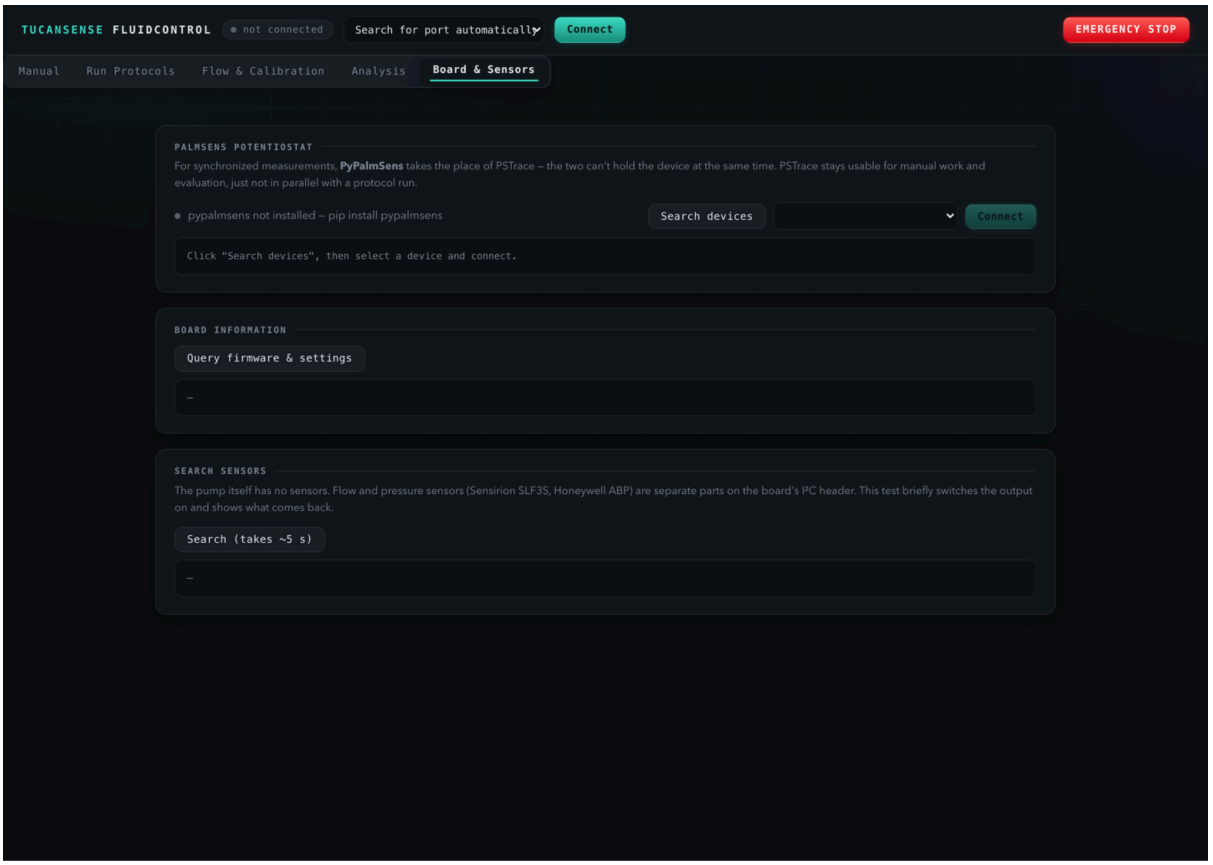
LIQUID: Water | CHANNEL: 1 | AMPLITUDE: 250 Vpp | FREQUENCY: 100 Hz

Calculate | This operating point must already be calibrated above.

Calibrate first, then this can answer "100 µl in how many seconds?".


RESULT
Ready – Levodopa in umol/L
window 0–0.4 V · centre 0.15 V
CONCENTRATION (UMOL/L)
3.0246
IP (UA)
39.578264
SENSUS ZONE
BLUE · 1 pt
LIVE MEASUREMENT
Streams while a scan runs. After it finishes the saved curve is analysed automatically and the peak fit appears below.
Nothing measuring right now
PEAK FIT
RESULT TO SHOW
DEMO_levodopa_3uM
Show
RECOMPUTE
Re-analyse
measured
fit
background
– if the fit ignores the peak, the window is wrong.
Current (uA)
40
20
0
0.1
0.2
0.3
0.4
Potential (V)





Link for Github repo

https://github.com/Noor-12-maker/TUcanSense/edit/main/README.md